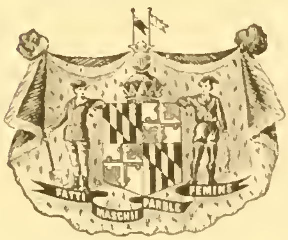
MARYLAND GEOLOGICAL SURVEY.

WM. BULLOCK CLARK, STATE GEOLOGIST.

THE BUILDING AND DECORATIVE STONES OF MARYLAND



Containing an

Account of their Properties and Distribution.

BY

GEORGE P. MERRILL AND EDWARD B. MATHEWS.

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PART II

THE BUILDING AND DECORATIVE STONES OF MARYLAND

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THE PHYSICAL, CHEMICAL, AND ECONOMIC PROPERTIES OF BUILDING STONES

BY

GEORGE P. MERRILL

GENERAL CONSIDERATIONS.

There are, in Maryland, four general classes of stone possessing such natural qualities as to make them available for constructive as well as ornamental purposes. These four are (1) the granites and gneisses, (2) the common limestones and dolomites; the marbles (crystalline limestones and dolomites); (3) the sandstones and conglomerates, and (4) the argillites or slates. In addition to these there are certain basic eruptive rocks used locally for purposes of rough construction, and other altered forms of eruptive rocks like the serpentines, which in some instances are of such color and texture as to render them of value as verdantique marbles. The individual characteristics of each of these groups will be taken up in detail later; in this preliminary chapter we will dwell rather on their geographic distribution in the state; and since this is due to geological causes, we will touch first upon the matter of their origin and the agencies which have been instrumental in making them accessible.

Classification.

From a geological standpoint all those rock types mentioned above may be classed as (1) eruptives, (2) clastic sedimentaries, and (3) metamorphics. The first include only those types which, like granite and the gabbros, have resulted from the crystallization, and subsequent exposure through erosion, of molten matter forced up into overlying strata. The second includes those rocks made up either of fragments of older, pre-existing rocks, or of calcareous materials derived from the

shells and stony skeletons of mollusks, corals and other lime-secreting marine animals. They are in short indurated beds of clay, sand, gravel or calcareous mud which have been deposited on ancient sea-bottoms. The third group comprises rocks of both the first and second, which have been changed from their original condition through processes known as metamorphic, and which usually accompany such foldings of the earth's crust as are incidental to the production of mountain chains.

Diversity of Resources.

Such being the case it is evident at once that the more diversified the landscape by hills and valleys, the greater will probably be the variety of materials. In regions abounding with mountain chains

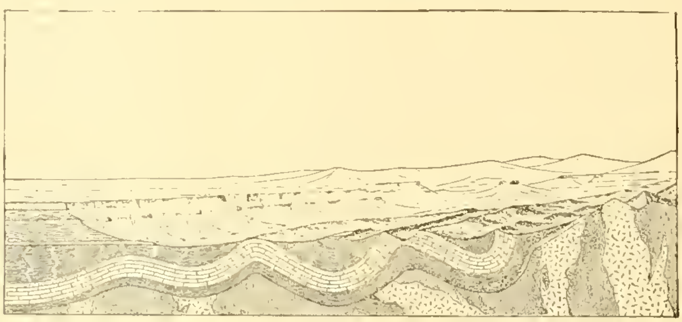


Fig. 1.—Ideal figure showing structure of the earth's crust (after U. S. G. S.).

we may look for a greater variety of materials than in the level plains. This not merely because such have here been formed, but because through uplift and erosion they have been made accessible.

By reference to a map of the United States it will be seen that the state of Maryland, in an east and west direction, stretches almost entirely across the Appalachian Mountain System. It occupies such a position with reference to this uplift and the less disturbed areas to the east and west as to lead us to expect a great diversity of materials even had not actual exploitation already shown them to exist. There is indeed probably no state in the American Union of the same area, that can be made to show a greater diversity in geological resources.

Geological Conditions.

In order to gain a satisfactory idea of the relationship of these various classes of rocks, let us consider for a moment the diagram given below.

FORMATION AND PRESENT POSITION.

The oldest rocks of which we have knowledge, and which seem to form the floor upon which have been built up all those since formed, are rocks of the gneissic and granitoid group. These, through superficial disintegration and decomposition, have yielded silts, sands and gravels, which carried by stream action to the seas have been spread out in approximately horizontal layers to be once more consolidated into stony matter, and perhaps in part metamorphosed, as will be described later. Such being their method of formation, it is easy

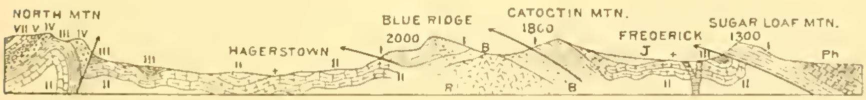


Fig. 2.—Generalized section from Sugar Loaf Mountain to North Mountain (after Williams).

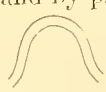
to see that these later formed rocks would naturally lie in parallel beds, the oldest, or first formed, on the bottom and the youngest at the top. And as the character of the material forming these sediments differed from time to time, both in texture and in chemical composition, sometimes being mere clay, sometimes sand, gravel, or calcareous matter, so it will be perceived these beds may differ, and we may have in the same horizontal series, sandstones, shales, limestones, slates and conglomerates. The character, thickness and lateral extent of such beds, vary almost indefinitely. As a rule, the beds of conglomerate are the least extensive, while the sandstones, limestones and shales may cover areas of many square miles.

That these beds of stratified, or sedimentary rocks as they are called, are not in all cases still lying horizontally, the oldest deeply buried and inaccessible, is due to the folding and faulting to which they have been subjected incidental to the formation of the Appal-

achian Mountains. Their present position is shown in Fig. 2, which represents an actual section across the State between Sugar Loaf Mountain and North Mountain.

Accompanying this uplifting there were in many instances large quantities of igneous rocks forced between the older strata, or into the rifts and fissures by which they were traversed, or in the form of immense domeshaped masses beneath folds, as shown at R in the section. These cooled to form trappean rocks, diabases, peridotites and in some cases granites.

But the uplifting was productive of other effects than that of merely rendering accessible. As is well known, pressure generates heat and heat accelerates chemical action. A series of chemical processes was thereby set in motion which resulted in a more or less complete change in the structure and general textural features of the rocks, as well as, in some cases, in color and in composition. Through these agencies many of the beds of limestone became converted into marbles, the sandstones into schists and the argillites into cleavable slates, suitable for roofing purposes.

In some instances this uplifting and metamorphism has gone on to such an extent as to practically ruin the stone for commercial purposes. The reader can perhaps best gain an idea of what has occurred by taking a pile of writing paper or an ordinary magazine or paper-covered book, a half inch or more in thickness, and by pressing against the back and edges and throwing it into a  shaped fold. By making first a pencil line directly across the edges at the end, it will be observed that, after the folding, this line is no longer at right angles with the leaves, but cuts diagonally across them at an angle dependent upon the amount of folding. This means, of course, that the sheets of paper have moved over one another slightly. Now fancy that each sheet of paper, or page of the book, as the case may be, represents a bed of stone, from a fraction of an inch to it may be several feet in thickness, and that all is weighted down by overlying rocks to such extent that the simple slipping of the beds one over the other as with the paper becomes a matter of great difficulty. When then the folding takes place, it is accompanied by more or less crushing and fracturing, and lines of

weakness, if not absolute rifts, are opened. Moreover, if the beds do not slip but remain themselves approximately stationary with relation to one another, it will readily be seen that those in the upper part of the fold will be subjected to a stretching process, perhaps even to the point of fracturing, while those in the lower portion will be correspondingly squeezed and crushed as shown in the figure. Between these two extremes will be a zone practically unaffected, and known to geologists as the zone of *no strain*. Now it is obvious that the condition of the material to be found in one of these folded areas will depend upon what portion of the fold is accessible. If erosion has exposed the materials in the zone of no strain (*A C B*)

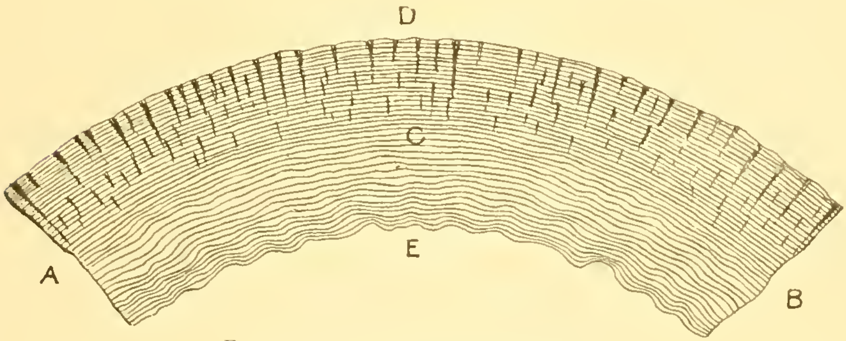


FIG. 3.—Folded rocks (after Van Hise).

it may be good, but if only the superficial beds (*D*) or the very lowest (*E*) are accessible, the materials may be all so seriously shattered as to be full of joints, dry seams and other defects, so as to render the production of blocks of large size an impossibility. Small samples of great beauty may be found in abundance, but the beds as a whole are worthless. This condition of affairs actually exists in many parts of Maryland and Virginia, and in the latter state considerable sums of money have in one instance at least been lost in attempting to develop a quarry.

VARIABILITY IN COMPOSITION AND STRUCTURE.

There are other geological features which are of importance to the quarryman.

Stones which were laid down as sediments on seabottoms are more

variable both in composition and structure than are those of eruptive origin. This for the reason that the character of the sediments deposited, from time to time, vary. We may thus have in the same vertical section rocks varying from conglomerates to sandstones, layers of sandstone alternating with shale or with limestone. Sound, firm beds of desirable material may be separated from one another by layers of shale which are absolutely worthless; beds of white homogeneous marble may be interbedded with impure layers carrying pyrite and micaceous minerals which wholly ruin it for commercial purposes. In quarrying, all these matters have to be taken into consideration, since, as waste products they must be removed, and the proportions existing between such and the merchantable stone may be the sole factor in deciding whether any quarry can or cannot be worked successfully.

Again, the amount of tilting and crushing beds have undergone during the process of uplifting is an important item. If the beds lie nearly horizontally and quarrying is commenced upon the upper beds, it is obvious that only one grade of material can be produced at a time. Each layer, as it is passed through successively, as the quarry increases in depth, yields its own grade of material which may or may not agree with that above or below. This is the case in the quarries of brown sandstone in Connecticut. When a quarry is opened in a hillside, or ravine, where a number of beds have been exposed through erosion, or on the upturned edge of beds steeply inclined as in the sketch, it is obvious that the quarry may at the same time be producing a great variety of materials. Some of the marble quarries of Vermont, for instance, which are opened on such upturned edges, produce from the various beds which are being worked simultaneously, marbles of pure white, clouded, dark veined, light water blue and dark bluish or greenish tints, the colors being dependent upon the amount and character of the impurities in the original sediments.

POSITION OF BEDS AND EXPENSE OF QUARRYING.

The position of the beds has, further, an important bearing on the cost of quarrying. It is self-evident that where the beds lie almost horizontally, and quarrying is resolved into merely cutting through

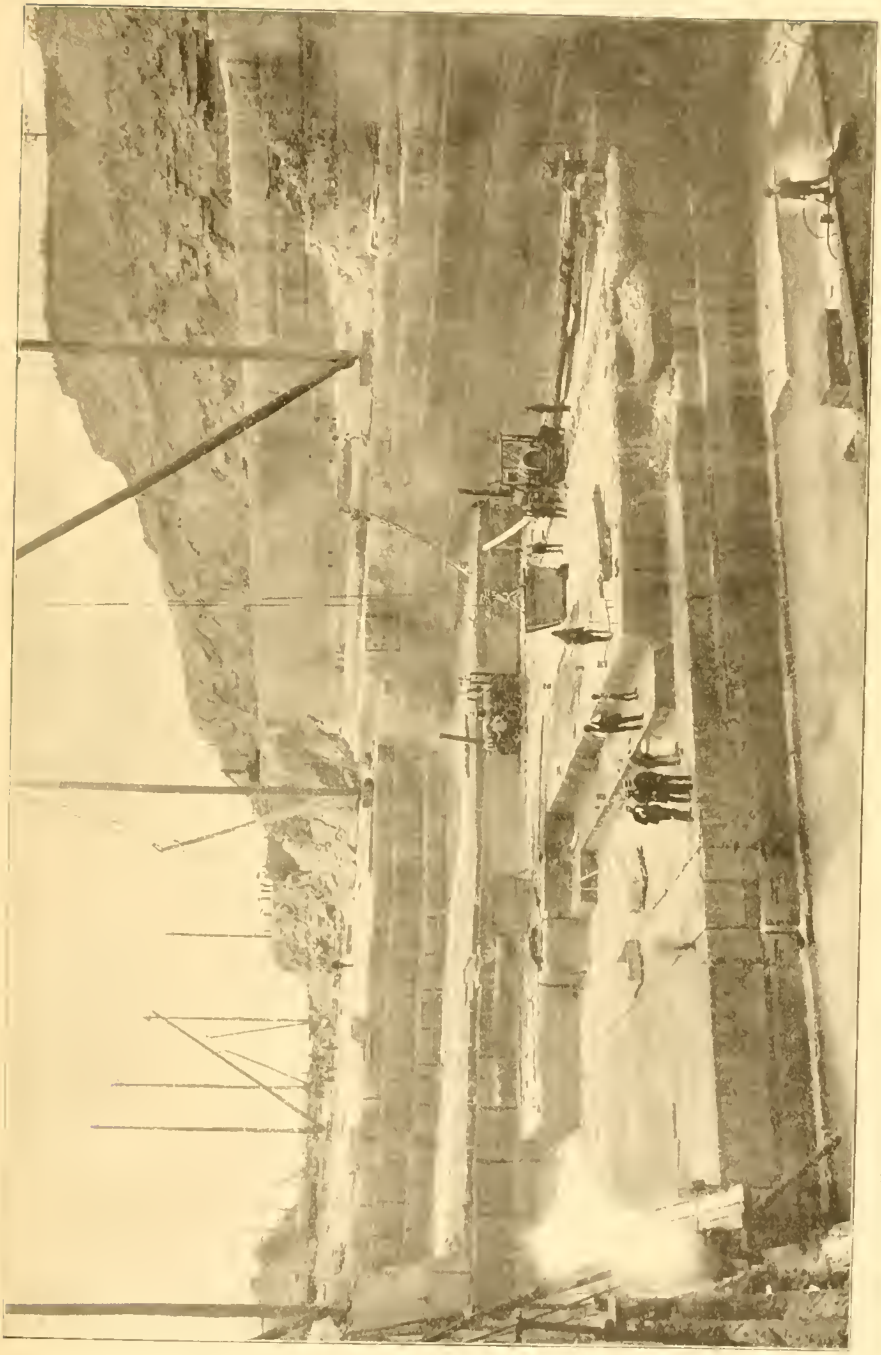


FIG. 4.—Quarry in horizontal rocks (furnished by American Hoist and Derrick Co., St. Paul, Minn.)

one bed after the other, as in the sand and limestone quarries of the upper Mississippi valley. The work can be carried on comparatively cheaply, provided that there is not too much preliminary stripping (Plate IV, Fig. 1). When, however, the beds stand at high angle, or are exposed only in a hillside, quarrying must be carried on either on a highly inclined floor, as in the quarries of gneiss north and west of Baltimore, or directly across the edge of beds, whereby considerable extra trouble and expense are involved.

THICKNESS OF BEDS.

In looking for new quarry sites, the geological structure of the country should always be taken into consideration. When the beds

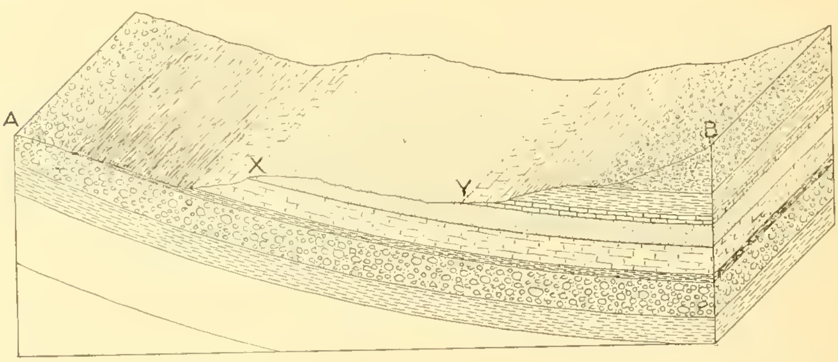


FIG. 5.—Diagram showing relation between thickness and exposure of beds.

lie horizontally it is obvious that the character of any but the uppermost beds can be ascertained only by investigation in hillsides and along the banks of ravines. Where they are highly inclined, it is in many instances sufficient to explore superficially along a line at right angles with the lateral extension, or *strike* of the beds, as it is technically called, that is to say, to follow along the line *A B* in Fig. 5.

The character of the various beds exposed can thus be ascertained, and when one sufficiently promising is found, its extent can be best made out by following it out along the line of strike.

Since the actual thickness of a bed of stone may be a matter of importance, it may be well to state how this can be best ascertained.

It is obvious that with beds inclined as in the figure, the width of exposure on the immediate surface is vastly greater than that of the true thickness of the bed itself. In such cases the apparent thickness is greater the smaller the amount of inclination.

Sir Archibald Geikie, is his Text Book of Geology, gives the following general rule to be followed when the inclination is less than 45°, and it is in such cases that the greatest discrepancies exist. The real thickness of an inclined strata, or bed, may be taken to be 1/12 of its apparent thickness for every five degrees of dip. That is, if, as in the sketch we have a series of beds outcropping on the surface along the line *A B* and dipping as shown, to the right, at an angle of 15°, the actual thickness of one of the beds, *X Y*, will not be the distance—say 100 feet—measured between these points, but 1/12 of 100 multiplied by 3, or 25 feet.

The amount of dip which beds may have and the character of the overlying rock should receive careful consideration before quarrying is commenced. In the case shown in the figure, if *X* — *Y* is the workable bed, it is evident at once that the quarry must sometime cease to be an open cut, and must then be followed underground. If the overlying rock forming the roof is sound and strong, this can be done with comparative safety by leaving occasional pillars for support. But if of a weak, or friable nature, it must be continually removed by stripping, thus increasing the cost. It is fortunate that in the majority of cases the amount of area exposed on the immediate surface is so large that it is not necessary to follow the beds to great depths, though in Vermont some of the marble quarries are even now over 200 feet in depth and partake more of the nature of mines than quarries, as the word is commonly understood. Naturally such deep quarries are much more expensive to work since not only must the cost of hoisting both merchantable material and waste be very considerable, but steam pumps must be continually at work to carry off the water which would otherwise collect to a depth of very many feet, even filling the entire quarry to within a few feet of the surface.

BEDDING AND JOINTING.

Among the unaltered eruptive rocks there is a total absence of bedding planes or other like structural features, the rocks being homo-

geneous and capable of being worked with almost equal facility in any direction, presenting on all sides the same appearance. Such do, it is true, have two definite directions at right angles with one another, along which they can be relied to split most readily. These are known as rift and grain, and though wholly inconspicuous to the ordinary observer, are readily detected by an experienced stone cutter. Bedded and stratified rocks, on the other hand, almost invariably present readily recognizable structural features. It rarely happens that an unaltered or even metamorphosed sedimentary rock is of such uniform composition that the lines of bedding, the original lines of deposition, are not easily traced. Along these the rock will split more easily than across them. Such lines when too pronounced may be a great detriment, not merely as concerns appearances, but what is of more importance, as affecting the weathering qualities of the stone also.

Such stone, when used in ashlar work, are often sawn or split parallel with the bedding, since not merely can the work be done in this manner at less cost, but a face of more uniform color and texture is thus obtained. That the custom is open to serious objection is noted in another chapter (p. 93).

Joints in rocks are matters of interest for still other reasons than those noted above, since upon their character and abundance is largely dependent the size and shape of blocks that may be extracted. To illustrate this point more fully: Plate IV, Fig. 2, shows a quarry in which the rock is traversed by a series of nearly horizontal joints so strongly developed that very little labor is necessary to free the sheets one from another. Large, flat blocks, with beautifully fresh and even surfaces that can be cut up to any desired size, even to sizes too large for transportation, can thus be readily and cheaply obtained. Such quarries will furnish blocks for building, for monumental work, for monolithic columns or for any purpose to which the rock is lithologically fitted. In other cases, where it may be these horizontal, or *bottom* joints, as they are called, are equally well developed, there exists a second series of vertical joints running at right angles with the first. Such necessarily limit the length or breadth of the blocks

Fig. 1.—HORIZONTAL BEDS.

Fig. 2.—PROMINENT "BEDDING" JOINTS.

obtainable. These quarries are best suited for the production of ordinary building and monumental material, and are commonly spoken of as block quarries in distinction from the sheet quarries above noted.

It is obvious that in either of the cases above noted, the joints, provided they are not too near together, and not discolored by sap, are of positive benefit to the quarries. It is possible, however, that owing to their abundance and to the angle at which they cut each other they may be decidedly detrimental or even ruin for architectural work what might otherwise be a good quarry. In the view shown in Plate V, Fig. 1, we have a quarry traversed by at least three sets of very conspicuous joints cutting each other at sharp and obtuse angles. The result is that natural blocks, though easily obtained, are of limited size and of such irregular shape that every one must be plugged or otherwise squared and dressed down before it is available. A quarry thus jointed cannot compete in the production of blocks of prescribed size with such as are described above, but can be worked economically only for random rubble, or for square blocks where so situated as to have particularly favorable facilities in the way of extraction and transportation.

Effects of Weathering and Erosion.

All rocks, without exception, when exposed for a sufficient length of time to the atmosphere, undergo a process of disintegration and decomposition, or weathering, as it is commonly called, whereby they become converted superficially it may be into sand, gravel and clay, and on the immediate surface into soil. This process of degeneration, which will be described in detail later, has been going on throughout the many thousands of years which have elapsed since the rocks were raised above the ocean level, and still continues. No portion of the land areas have escaped. By its means, accompanied by the erosive action of running water and of glacial ice, many hundreds and even thousands of feet in vertical thickness of material have been removed from the land areas, and carried seaward. The soil itself is but a transitory phase of this weathering process, being continually removed above by the water of rains, and renewed below by further decay of the underlying rock. Where the erosive action of water and of ice

has not been too excessive, there exists a blanket of varying thickness of this rotten material overlying the still sound rock, into which, in many a deep cutting, it may be seen to pass by imperceptible gradations. The fact that all portions of the land are not alike covered by this blanket of soil, clay, sand and gravel, is due to the unequal erosion mentioned above. At a comparatively recent geological period the condition of affairs now existing in Northern Greenland prevailed all over New England, New York and portions of Pennsylvania, and a large portion of the Central States north of the Ohio and east of the Mississippi River. Huge glacial ice sheets, in some cases thousands of feet in thickness, buried the land, and, travelling slowly southward and westward, plowed down through this rotten material, or dragged and pushed it along, even grinding into the hard fresh rock as a workman with file and plane would cut down through the discolored and rotten matter on the surface of a piece of timber till the sound fresh wood was reached. The result is of more than theoretical interest. Throughout the glaciated areas, and particularly along the New England Coast the rocks are found to-day hard and fresh to the very surface, as shown in Plate V, Fig. 2, necessitating no stripping, and scarcely any preliminary work prior to the quarrying of merchantable material. The immediate surface, for the depth, it may be, of but the fraction of an inch, is slightly deadened or discolored. Below this the stone is strong, clear and durable. In the regions beyond the limit of the glacial action, however, the rocks are still covered with the mantle of debris, excepting so far as removed by water. But as the erosive power of water is so much less than that of ice, so here we find the sound stone covered by a mantle of from one to many feet of earthy and discolored material which must all be removed before actual quarrying operations can commence. Even when sound rock is struck it often occurs for a time only in bowlder-like masses, owing to the penetration of the decay most deeply along pre-existing joint planes. This condition of affairs is shown in Plate XIV, Fig. 1. The same condition exists, often in a more exaggerated form throughout the Southern States, as in the marble regions of Tennessee, and to it is due the prevalent idea that

the stone here does not occur in true beds, but only in "bowlder formations." When apparently fresh stone is found on the immediate surface, it is often weakened through a loss of cohesion between its particles by the expansion and contraction of ordinary temperatures. This is particularly true of the granitic rocks.

These facts are dwelt upon here in detail, since they must always be taken into consideration in the opening of new quarries. It is due to such causes in part that the northern quarriers are enabled to compete so successfully in the markets of Washington and Baltimore with those nearer at hand. Cheaper transportation by water and ready accessibility to shipping points are, however, important factors, though the advantages thus gained are in part offset by a more rigorous climate, whereby actual quarrying operations must be limited to the warmer season of the year only.

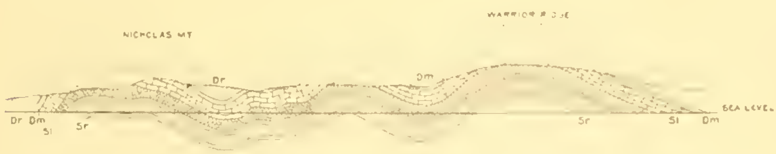


FIG. 6.—Section across Western Maryland showing restored folds.

In all this discussion, it is well to remember that the natural surface of the earth is undergoing constant change through erosion and deposition. Every rainfall and running stream carries from the higher to the lower levels more or less rock detritus, a part of which is even transported to the sea, to be permanently lost from the present land areas. In short, the surface is being constantly lowered, and deeper lying rocks are successively exposed. Just how much the surface has been lowered in bringing about the present condition of affairs, it is perhaps hard to say. What might at one time have been the land surface had no erosion taken place, may be shown in the accompanying section across western Maryland through Warrior Ridge and Nicholas mountain in Allegany county. In this section the continuous lines represent, so far as is possible on so small a scale, the present land surface, while the dotted lines indicate the portions that have

been eroded away. Where would have been hills are valleys now, and in regions where but for erosion would have been found monotonous stretches of sand or limestone, each covered by its layer of soil, are now accessible by means of their upturned edges, beds of a great variety of colors, texture and composition belonging it may be to widely different geological horizons.

It may be remarked here that the character of the material on the immediate surface, is not always a sure indication of that which is to be found beneath. This is due to the variability in weathering qualities displayed by rocks of different kinds, a matter which is dwelt upon in some detail in the following pages.

Such imperfections as dry seams and joints in rocks are invariably more conspicuous in the superficial portion of the quarries, than at greater depths simply through the mechanical action of heat and frost or the decomposing action of water. On the surface such may manifest themselves in the form of open cracks, and lines of discoloration, which perhaps wholly disappear or become inconspicuous at comparatively slight depths. It must be remembered, however, that the absence of these defects does not necessarily carry with it an absence of such tendencies as shall cause them to develop under favorable conditions. The writer has in mind a quarry in a more northern state in which on the immediate surface the stone was to be had only in comparatively small, angular blocks owing to the presence of innumerable sharp open joints. At a depth of perhaps 20 feet the open joints had disappeared, and *apparently* sound blocks of almost any size were obtainable. Careful examination of these blocks, however, revealed the presence of sharp, straight lines, as fine as a pen scratch, each one of which would correspond to an open joint on the surface, but which so long as protected from heat and frost, remained quite inconspicuous. It is safe to say that in no case can joints, which are conspicuous as such on the surface, be relied upon to disappear entirely at any depth likely to be reached by quarrying operations. They are a product of deep-seated agencies, and extend to depths which so far as practical quarrying is concerned might as well be without limit.

The solution, discoloration, and decomposition which goes on along such joint planes and lines of weakness may however cease to be appreciable or important at depths comparatively insignificant. The ferruginous discoloration, or so called "sap," which is frequently found penetrating blocks of stone, particularly of granite, for an inch or more along these joints, is due merely to the decomposing action of percolating water, and below the permanent water level, may quite disappear. Once removed from the quarry bed and placed in the walls of a building, the conditions are so changed that there is no probability of this form of staining making its appearance excepting where, it may be, the rock carries appreciable quantities of iron sulphides (see p. 91). In calcareous rocks, the presence of joints is often exaggerated through the solvent action of water, which percolating downward carries away the material in solution. Jointed beds of marble may therefore, on and near the surface, be reduced to disconnected bowlder-like masses, as is sometimes the case in the marble regions of Tennessee. The extent to which such solution has gone on is ever variable, sometimes to a depth beyond the limits of practical quarrying, and sometimes to but the depth of a few feet below the surface. In some cases, even within the limits of Maryland, comparatively thin beds of what was otherwise a most beautiful marble, have been so eaten out by this solvent action as to leave only a fractional part of the original material. Here and there may be found outcrops of very promising stone, but when the beds are traced along for very short distances they are found quite obliterated. To illustrate this point more fully:—The writer was called on not long ago for an opinion relative to the probability of an undeveloped quarry being able to furnish sufficient material of a certain grade to warrant the letting of a contract. On examination, there was found in one locality, and almost on the immediate surface, a bed some two feet in thickness of a beautiful fine white, almost translucent marble. This dipped at a low angle beneath the surface soil and to the inexperienced observer might, and did seem very promising. On careful inspection, however, such an inspection as could be made only by one acquainted with the geological structure of the country and the action of the

atmosphere on rocks of this class, it was discovered that, on all sides, everywhere indeed within reach of practical quarrying operations, this bed had become almost entirely dissolved away, leaving only here and there small areas too insignificant to be worthy of consideration. By exploring along a deep trench that had been opened across the face of the bed, it was discovered, too, that the lower beds were not only quite siliceous and hard but variable in color and often carried the deleterious material pyrite. In short, all of the material of any value that the quarry could be relied upon to produce was the small amount actually in sight, aggregating at most but a few thousand cubic feet. Unfortunately the "practical" quarryman was in this case unwilling to accept the conclusions of the geologist and persisted in attempting to develop a quarry, only to discover when too late that he was wrong and that both his money and his energies had been wasted.

As a general rule the solvent and decomposing action of water goes on most rapidly in the softest and weakest portion of the rock, so that the residual bowlder-like masses may represent the better quality of the material. Excepting then that nature's method is extremely wasteful such results can be considered as scarcely detrimental. A quarry under such conditions may be actually producing a better, more uniform class of material, than one which has escaped solution altogether.

In making search for new localities for opening quarries, it is always well to note the manner in which the individual beds have weathered. The soundest and best will as a rule be found standing out in relief while the more perishable have crumbled away.

All stone as it lies in the ground contains a certain amount of interstitial water, which holds in solution more or less mineral matter. This is commonly known as quarry water. When stones are removed from the quarry bed, this water is drawn to the surface and evaporated, leaving its mineral matter to serve as a cement to bind the grains together. A superficial induration or hardening thus takes place. This phenomenon has been long since recognized by quarrymen, though the cause of the same has not been generally known.

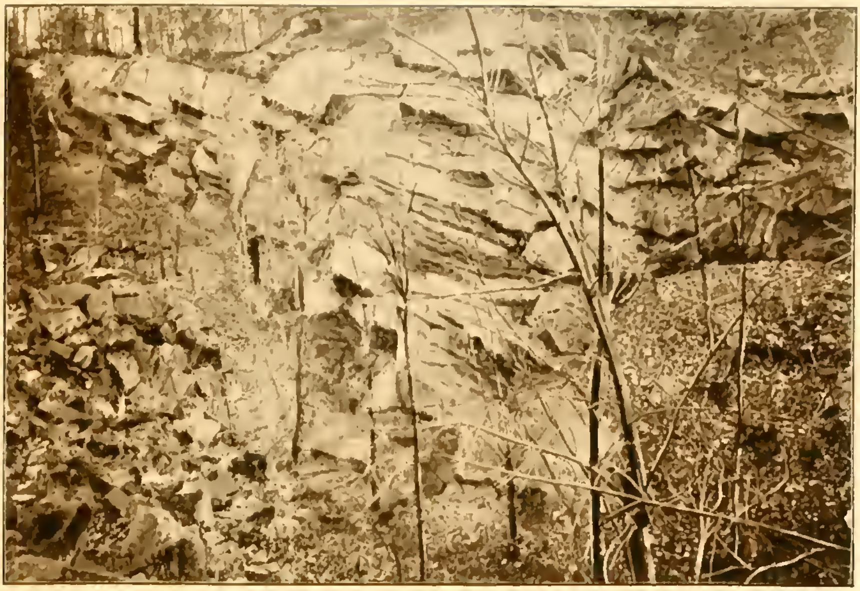


FIG. 1.—QUARRY SHOWING SEVERAL SERIES OF JOINTS.

FIG. 2.—GLACIAL STRIPPED QUARRY.

That a stone is soft when first quarried and hardens on exposure, is one of the commonest arguments used by quarriers with reference to their material, though they fail to remember that such induration may be temporary, and the rock in time crumble in spite of it. Sandstones are peculiarly liable to such induration, even in exposed outcrops in the quarry bed, so that casual inspection will give quite erroneous ideas as to the actual quality of the stone. A slight change in color, from the surface downward, is also a not infrequent occurrence, as is noted in the chapter on Weathering (p. 90).

Color of Rocks.

The subject of the color of a rock, when first quarried, after prolonged exposure, and after working is one that should be briefly considered. Among siliceous crystalline rocks the colors are due mainly to the presence of colored minerals, or to the physical condition of the feldspars. Thus the gray color of granites is due largely to an admixture of white feldspars and black mica or hornblende; the red colors to red feldspars; the dark greenish, sometimes almost black colors to clear pellucid feldspars, and the white, to white feldspars. The dark colors of the diabases and the gabbros are due to the pellucid feldspars and the dark pyroxenes they carry. Pure limestones and dolomites are white simply because that is the color of the calcite or dolomite which forms their chief constituent. The dark color common in this class of rocks is due as a rule to the presence of carbonaceous matter: the red, to iron oxides, though the pink and red colors of some of the onyx marbles seem to be due in part also to organic matter. The red, brown and yellow colors of sandstones are due to iron oxides. The changes in color which these rocks are likely to undergo, on exposure, are noted in the remarks on rock-weathering. It may not be out of place to state here, however, that nearly any feldspathic rock is likely to become lighter in color during the incipient stages of weathering owing to the opening up of the cleavage planes in the feldspars. It is for this same reason that the hammered surface of one of these rocks is of a lighter color than the natural rock face or polished surface. The impact of the hammer breaks up the granules on the immediate surface so that the light falling upon it

is reflected, instead of absorbed, and the resultant effect upon the eye is that of whiteness. The darker color of a polished surface is due merely to the fact that through careful grinding all these irregularities and reflecting surfaces are removed, the light penetrating the stone is absorbed, and the effect upon the eye is that of a more or less complete absence of light or darkness. Obviously then the more transparent the feldspars and the greater the abundance of dark minerals, the greater will be the contrast between hammered and polished surfaces. This is a matter worthy of consideration in cases where it is wished, as in a monument, to have a polished die, surrounded by a margin of hammered work to give contrast. Often when a piece of work of this nature is exposed, the contrast between hammered and polished work diminishes slightly owing to the gradual weathering out of the particles splintered through hammering. The contrast is less when the stone is wet than when dry, because the water fills all the little rifts and crevices and by its refracting power tends to produce the same effect as though the stone were polished.

Geological Age.

The matter of geological age is only of very general economic interest. It is indeed true that the process of metamorphism—the change from the amorphous or fragmental condition to one more or less crystalline—has as a rule gone on more extensively among the older rocks, than among those later formed, but the rule is by no means universal, and moreover metamorphism is not always productive of such characteristics as make a stone adapted for either building, monumental or decorative work. While metamorphism may render a stone crystalline, it may also render it granular and friable; while it may develop color, it may also develop schistosity and other blemishes. So far as the United States are concerned, one can say, however, that few stones are used to any extent that are of later date than the Triassic, and that few if any of our marbles are younger than Silurian, while nearly all our granites, as now quarried, belong at least to Paleozoic or Archaean times. Stones of later than Triassic age, are, so far as relates to the Eastern United States so friable, or so poor in color, as to be of little value.

The Strength of Stones.

Much has in times past been written on the subject of the crushing strength of building stones, and hundreds of tests have been made, the results of a few of which are given in this work. A few words only on the subject are here necessary. It is doubtful if in any but the most extreme cases it is necessary to continue this line of investigation. The results thus far obtained are sufficient for us to formulate general rules, and the average results obtained are so vastly in excess of all ordinary requirements that they may safely be ignored. A stone so weak as to be likely to crush in the walls of a building, or even in a window stool, cap or pillar, bears so visible marks of its unfitness as to deceive no one with more than an extremely rudimentary knowledge on the subject. It is rare to find a stone that will not show, under the methods of testing now in vogue, a crushing strength of at least 6000 lbs. to the square inch, while many stones, particularly those of the granite group, will range as high as 20,000 to 30,000 lbs. to the square inch. Since the first named amount is tenfold more than is likely to be required of it in any but the most extreme cases, the absurdity of making further tests is manifest. The few that have here been made, were made in recognition of the still prevailing—though mistaken—demand for tests of this nature. They show, as was to be expected, that the matter of the strength of those of the Maryland stones now on the market, may well be left out of consideration in the future, and this for the reasons above suggested.

In fact, it is the weathering quality of a stone more than its ultimate strength, that should concern us, and a careful examination of the natural outcrops, old quarry faces and buildings, will give a more correct idea to an experienced man, than will all the tests that can be made in the laboratory. This view the writer expressed some years ago,[1] and to it he still adheres with little fear of contradiction.

Geographic Distribution of Stone in the State.

By referring to the map of Maryland (Plate VI, Vol. I), it will be seen that the state is divided into three well defined topographic prov-

[1] Stones for Building and Decoration, Wiley and Sons, N. Y.

inces, which are intimately related to its geologic structure and hence have a bearing upon its mineral yielding capability. It will therefore be worth our while to devote a little space to a consideration of this branch of the subject, bearing in mind, the while, that much that is said here regarding Maryland is true to a certain extent of the entire Eastern United States.

The most easterly of these topographic provinces, known as the Coastal Plain, comprises the area between the Atlantic Ocean and a line passing N. E. to S. W. from Wilmington (Delaware) to Washington, D. C., through Baltimore. The region is about 100 miles broad in its widest part, and includes very nearly 5000 square miles of territory or about one-half the area of the entire state. It is characterized by broad level-topped stretches of country, which extend with gradually increasing elevations, from the Coastal border, where the land is scarcely at all elevated above sea-level, to its western edge, where heights of 500 feet and more are to be found. The underlying rocks are as a rule but slightly indurated, consisting mainly of clays and sands, sometimes locally cemented into ferruginous sandstones and conglomerates and never of such consistency as to be of value in their natural state for building purposes. We may therefore dismiss this portion of the state from further consideration.

The second province, known as the Piedmont Plateau, borders the Coastal Plain on the west and extends to the base of the Catoctin Mountain. It is nearly 40 miles in width in the southern portion of the region, but broadens toward the north until it reaches 65 miles in width, comprising altogether an area of approximately 2500 square miles, and including Cecil, Harford, Baltimore, Howard, Montgomery, Carroll and Frederick counties. As it is this province which furnishes by far the larger amount and greater variety of building stones and marbles, it will be worth the while to consider it in some detail. The Plateau, as a whole, is divided very nearly in its central portion by an area of high land known as Parr's Ridge, into an eastern and a western district. To the east of this ridge lie the gneisses, granites, gabbros, crystalline dolomites (marbles), serpentines, and roofing slates, the main portion of the area being occupied by the

gneisses, through which have been sporadically intruded the granites and gabbros which, by erosion, are now exposed in the form of isolated patches of comparatively limited extent, as shown on the map. The building marbles of the state are limited almost wholly to this eastern division, as shown in the areas north of the city of Baltimore.

This eastern division has, on account of its crystalline rocks and their complicated structure, a diversified topography. Along the eastern margin the land attains, at several points, heights exceeding 400 feet, reaching at Catonsville 525 feet above sea-level. To the west the country gradually increases in elevation until it culminates in Parr's Ridge, which exceeds 850 feet in Carroll county.

The drainage of the eastern district is to the east and southeast. On its northern and southern boundaries it is traversed by the Susquehanna and Potomac rivers, which have their sources without the area, while the smaller streams, which lie between them either drain directly to the Chesapeake Bay or into the two main rivers. Among the larger of the intermediate streams are the Patuxent, Patapsco and Gunpowder rivers, whose headwaters are situated upon Parr's Ridge. The Patapsco especially flows in a deep rocky gorge until it reaches the Relay, where it debouches into the Coastal Plain. All these streams have rapid currents as far as the eastern border of the Piedmont Plateau, and even in the case of the largest rivers are not navigable.

This last is an important item since it precludes the possibility of shipment of quarried material by other than rail, canal or wagon routes.

The western division extends from Parr's Ridge to Catoctin Mountain. Along its western side is the broad limestone valley in which Frederick is situated, and through which flows the Monocacy River from north to south, entering the Potomac River at the boundary line between Montgomery and Frederick counties. The valley near Frederick has an elevation of 250 feet above tide, which changes slowly to the eastward toward Parr's Ridge, and very rapidly to the westward toward Catoctin Mountain. Situated on the eastern side of the valley, just above the mouth of the Monocacy River, and breaking

the regularity of this surface outline, is Sugar Loaf Mountain, which rises rapidly to a height of 1250 feet.

The underlying rocks of this division are as a rule far less crystalline than those of the eastern, consisting mainly of blue gray limestone, red brown sandstones, phyllites, and other siliceous and argillaceous rocks which are largely unsuited for construction purposes and hence need no mention here. There are, however, in Carroll and Frederick counties several comparatively small included areas of highly crystalline limestones capable of furnishing in small blocks material of such color and texture as to make them of value as marbles.

The third or Appalachian region borders on the Piedmont Plateau and forms the entire western portion of the state. It includes the western portion of Frederick, and all of Allegany and Garrett counties, an area of some 2000 square miles. This is the most mountainous region of the state, consisting indeed of little more than a series of parallel mountain ranges with deep narrow intervening valleys which at the southern limit of the state are cut almost at right angles by the Potomac River. This area has as yet furnished practically nothing in the way of structural material though it does not necessarily follow that satisfactory materials do not exist. The rocks consist mainly of sandstones, shales and limestones, none of the latter being sufficiently metamorphosed to make them of value as marbles. The possible resources of this region will be discussed later.

Methods of Quarrying and Working.

In the work of extracting stone from the quarry, and reducing it to the desired shapes for use, there are two considerations of primary importance. These are, 1st, the accomplishing of the work with the least possible injury to the material, and, 2nd, the accomplishing of it cheaply. Unfortunately the two methods are almost directly opposed to each other, and equally unfortunately the cheaper methods are those, as a rule, most likely to produce injurious results. This last is only partially true, however, since where the work is carried on on a large scale, the better way proves in the end the cheapest. In many kinds of manufacture complaint is made that machine-made goods are inferior to those made by the old-time hand processes. In

stone work this is certainly not correct, however. With machines it is possible to produce better results, in less time than by hand methods. This is particularly true regarding quarrying, sawing, grinding and polishing. There are of course certain kinds of work, certain forms of finish, for the satisfactory performance of which no machines have been designed.

Before considering in detail the methods employed in stone quarrying and stone working, let us first consider the conditions under which the stone exists in the quarry, what difficulties are to be overcome, what methods can be pursued with safety, and what must be avoided. All stone that is used at all extensively for structural purposes has the property of splitting, or breaking with fairly flat and even faces, along two directions at right angles to each other. The direction of greatest ease is known as the rift, that at right angles as the grain. The cause of this tendency to split along definite lines is not fully understood. It is enough for our present purposes that it exists. The rift is often very pronounced, and its direction is indicated by and some is due to a parallel arrangement of the constituent minerals as in the gneisses and schists. In other rocks, like the more massive granites, it is wholly inconspicuous and the direction can be determined only by an experienced stone-worker. Nothing is more surprising to one who has given no attention to the subject, than the ease with which a workman, with no other tool than a square-faced hammer will break out by a few well directed blows a rectangular block of the required size and shape for street pavements, while an inexperienced person, with the expenditure of twice the amount of time and triple the amount of energy will produce only a shapeless mass, with bulging faces and rounded corners, utterly worthless and unfit for use. Here then are two important factors which must be taken into consideration. Another is the jointing. To this property attention has been called on p. 55, and the matter need not be wholly repeated here. It should be stated, however, that these joints may be either a help or hindrance to quarrying according to their prominence, abundance, and the directions at which they traverse the stone. As a very general rule those massive rocks which are extensively quarried owe their

availability to the presence of two series of joints which like the rift and grain cut the stone in directions practically at right angles with each other. This condition of affairs is described on p. 56, and a figure is given showing the utility of joints in quarrying. Hence nothing more need be said on the subject here.

Among sedimentary rocks—the sandstones and limestones—the better grades of stone lie in well defined beds, or layers, separated from one another by other beds of inferior or worthless material. The quarrier has to consider not only how to get out the good material, but also how to get rid of that which is worthless. One method must be resorted to for the first, and another less expensive for the second.

Another feature which must not be lost sight of, here, is the difference in degree of hardness and toughness of various classes of rocks. A method of treatment allowable in one case, as with granites, would be wholly impracticable in another, as with limestones. Fortunately those rocks which are so tender as to be likely to become injured by the more violent methods of quarrying, as by blasting, are sufficiently soft to permit of their extraction by other means. The quarrier has to remember that stones have but a comparatively small amount of elasticity, that they are brittle, and any sudden jar, like that from an explosion of powder or dynamite, is likely to develop flaws and fractures, which, while they may be quite inappreciable at first, become injuriously conspicuous by weathering.

But enough has been said to show that quarrying is not quite so simple a process as may have at first appeared. Let us now devote a few pages to a consideration of the methods in vogue.

The old time and simplest method of quarrying which needs be considered here, is that of blasting out the rock by means of powder exploded in a cavity made by hand drills. This method, aside from being too slow for modern purposes, results in the production of only irregularly shaped blocks requiring a proportionately large amount of labor to reduce them to the desired sizes and shape. Moreover, the explosion of a single, large charge of powder, is likely to produce a shattering which can be wholly done away with if the charge is distributed along a line among several holes which are exploded simul-

taneously. This method is rendered possible through the invention of a steam drill such as is shown in Fig. 7. As may be seen it consists of little more than a steam cylinder mounted on a tripod with

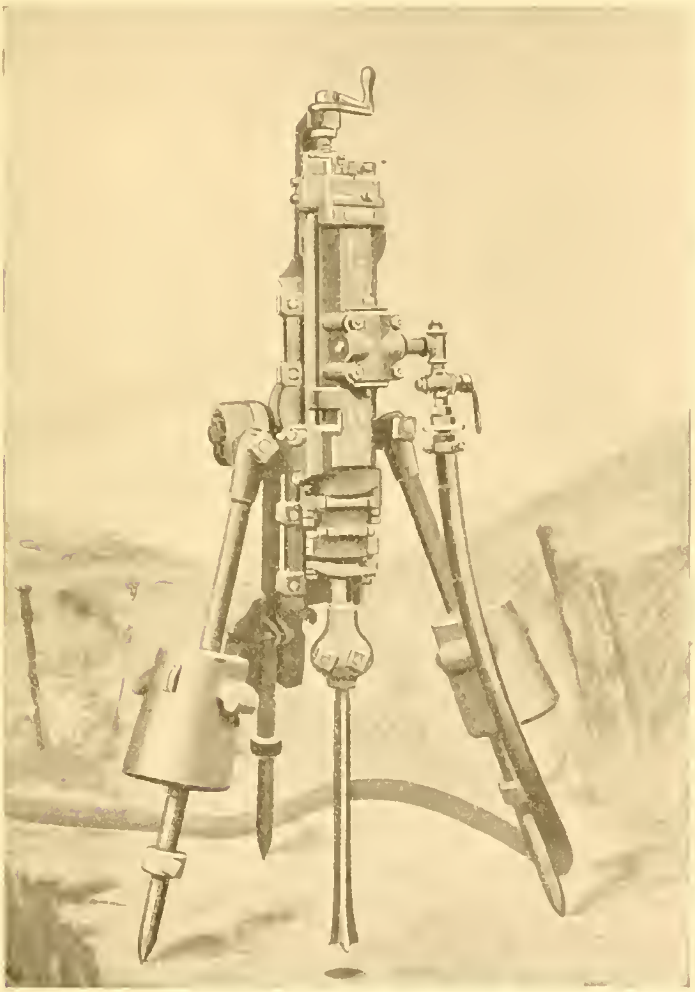


FIG. 7.—Ingersoll-Sergeant steam drill.

the drill attached to the piston. The machine is held in place by means of heavy weights on the legs of the tripod. The steam being

conveyed from the boiler to the drill by means of a flexible hose, which allows the use of the drill in any part of the quarry. A different form of drill answering the same purpose is shown in Fig. 8. By means of these machines a series of two or more holes are drilled along the line where it is desired the stone shall break. These are then charged lightly with powder, and fired simultaneously by means of electricity instead of by a fuse. The result is that a large mass of rock is freed from the quarry bed, with a comparatively slight amount

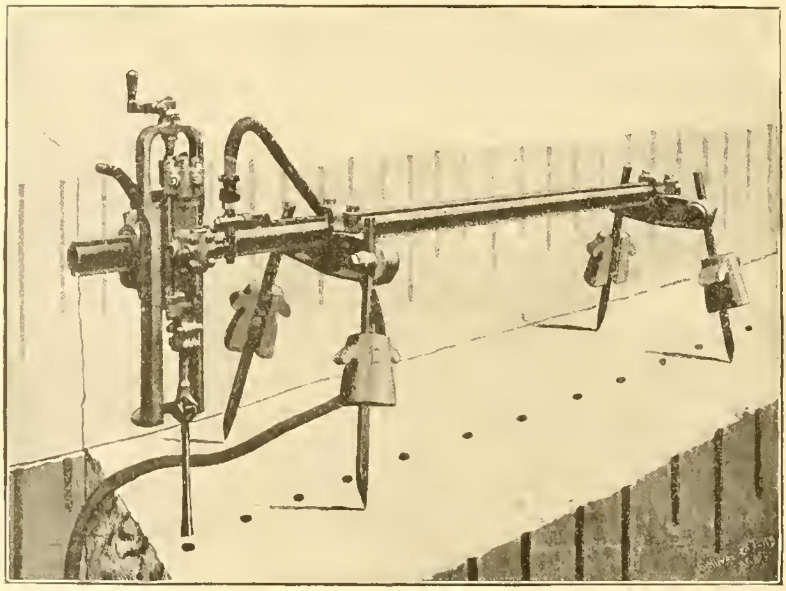


Fig. 8.—Ingersoll-Sergeant quarry bar drill.

of jar, the aim of the quarrier always being not to move the block any appreciable distance, but simply to free it, after which it is reduced to blocks of the required size by hand implements, to be noted later. Where the bottom joints in a quarry are well defined as at Vinal Haven, Maine, masses of granite some 300 feet in length and 20 feet in width have been loosened at a single blast.[1] In cases where bottom joints are not sufficiently developed, or are at too great a dis-

[1] Stones for Building and Decoration, 2nd Ed., p. 241.

tance apart, it is sometimes necessary to resort to drilling and blasting to free the rock from the quarry bed.

Once loosened from the bed, as described above, a block of granite or other hard rock, is cut up into desired sizes by means of plugs and feathers. By means of hand drills or a quarry bar drill, a series of

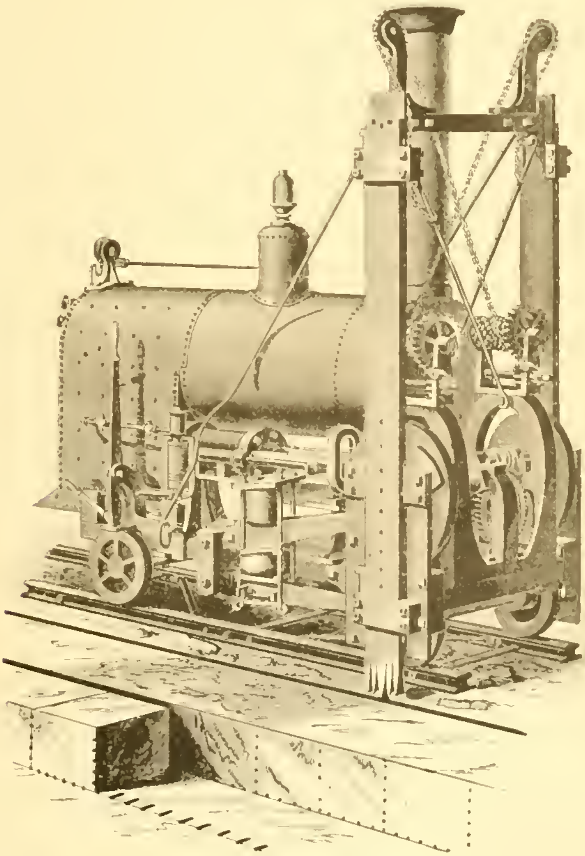


FIG. 9.—Wardwell channelling machine.

holes, not over an inch in diameter and a few inches deep, is drilled along the line where it is desired the stone shall break. Into each of these is then placed two half round wedge-shaped pieces of soft iron, the thicker ends downward, and between them is inserted a small steel wedge. When the wedges or plugs are all in place the workman

strikes them one after the other with his hammer, driving them all alike, thus producing a uniform strain along the line, until the block falls apart. The method is commonly known as "plug and feather" splitting. In the softer rocks, as the sandstones, a somewhat different method is resorted to. Instead of drill holes, grooves are first cut with picks, and into the grooves large steel wedges are

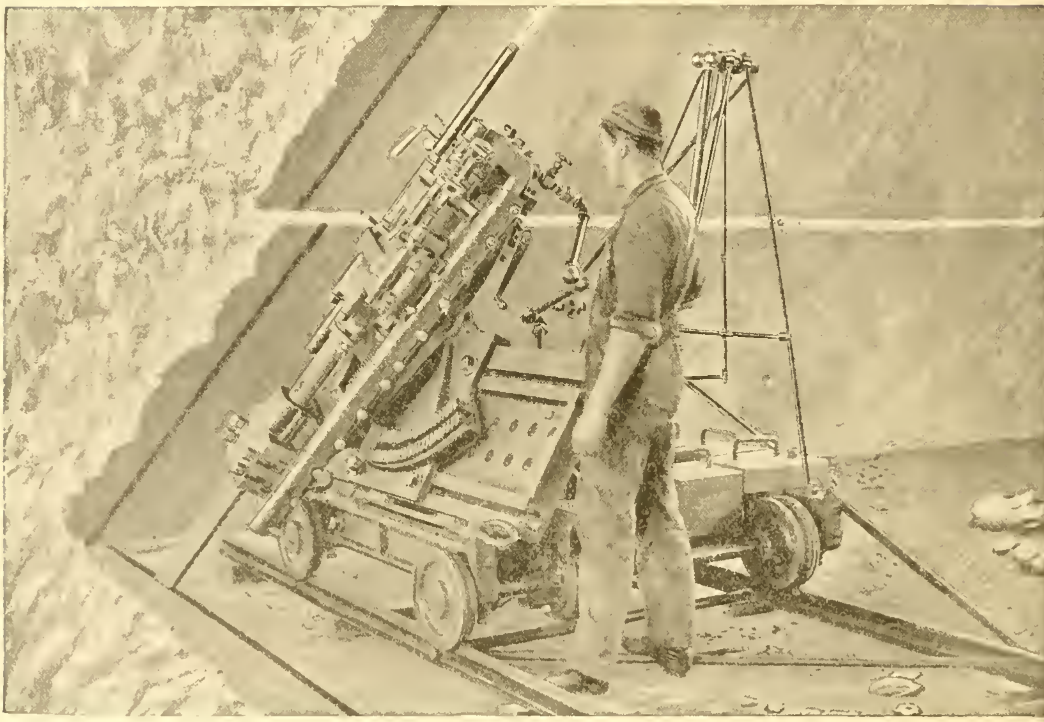


FIG. 10.—Ingersoll-Sergeant channelling machine.

inserted which are then driven with heavy striking hammers or sledges, in the same manner as before.

Blasting by means of powder furnishes the only available means for quarrying rocks of the granitic type, owing to their hardness. But the method should be used reasonably and with discretion. Material from a quarry where, as one sometimes reads, hundreds or even thousands of tons of stone have been loosened by a single blast,

should always be accepted with hesitation, if at all, for building purposes, since as above noted the jar from such a concentrated explosion is likely to produce incipient fracture and injuriously develop latent joints.

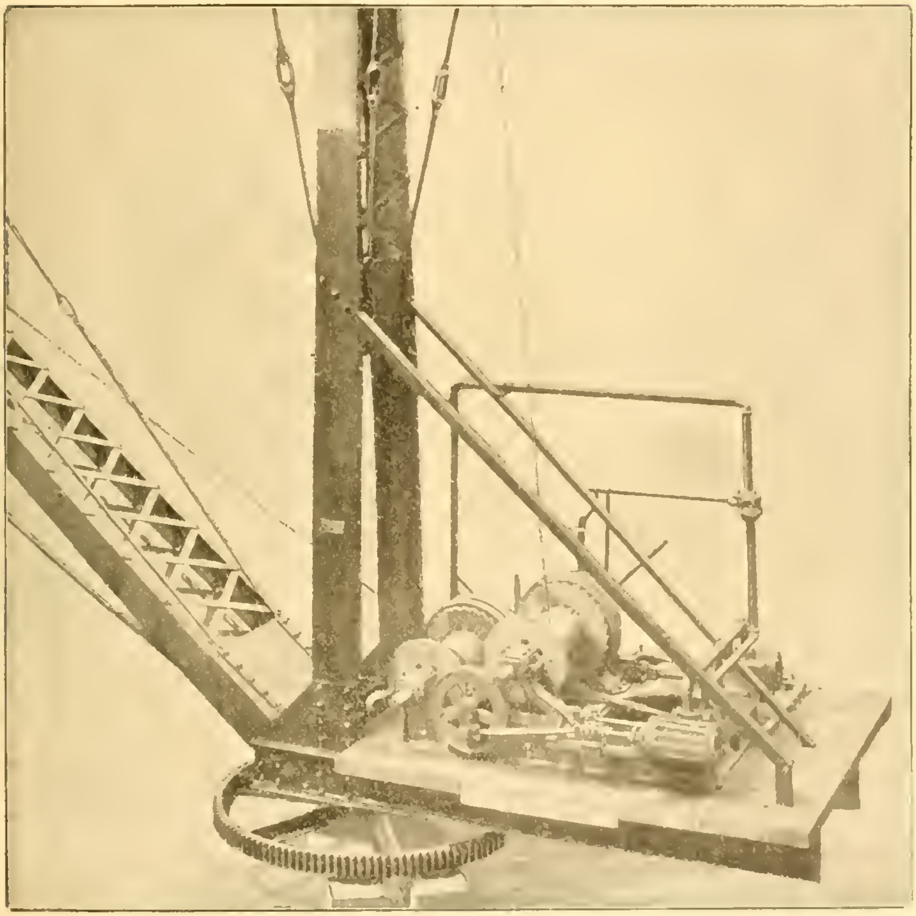


FIG. 11.—Revolving drum and hoist for derrick.
(Furnished by American Hoist and Derrick Co., St. Paul, Minn

In quarrying softer rocks like the sandstones, limestones and marbles, channelling machines are now used in nearly all American quarries. Two distinct types of these machines are used (Figs. 9 and 10).

but with both the results are essentially the same. The machines are constructed to run forward and backward over temporary tracks laid on the quarry floor and to cut as they go straight smooth channels into the stone beneath, the channels, by repeated passage of the machine, being cut to any desired depth up to perhaps six or more feet. The rock on the floor of the quarry is thus divided up into a series of

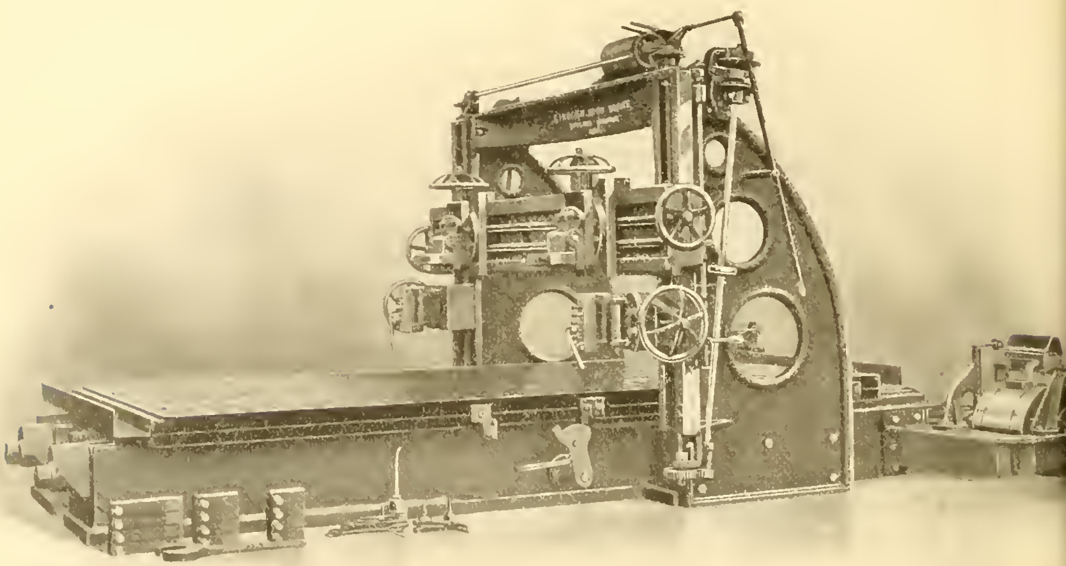


FIG. 12.—Lincoln stone planer.

blocks which need only to be freed from the quarry bed to become available. This freeing from the bed is usually done by means of machines known as undercutting or "gadding" machines. These are sometimes ordinary impact steam drills, or again diamond drills. In either case a series of holes is drilled along the desired line, and the stone then broken out by wedges, or perhaps by means of another machine which simply cuts out the partitions between the holes.

By the aid of such machines blocks of any desired size may be obtained, and what is of equal importance, selected material can be taken out with no possible danger of injury as by blasting.

The removal of blocks from the quarry to the shed is accomplished by hoists using horse, steam or electricity for power, the running-gear passing over the arm of a derrick as in Plates X and XIV, or through a truck on a cable as in Plate XXXII. The cable permits the lifting of blocks from any portion of the quarry along the line of the main cable, the derrick handling all of the material within a given distance of its base. The time and expense involved in pulling around the arm of the derrick by a rope may be lessened by the use of small drums connecting with a horizontal wheel as shown in the accompanying figure (11) or in less detail in the photograph of the Port Deposit quarries (p. 144).

Once removed from the quarries stones are cut and finished by processes, which within certain limits vary according to the hardness of the material, though the nature of the rift or bedding naturally has much to do in the matter. Granites and hard rocks of this nature are as a rule reduced to the desired size and shape by plug and feather splitting and by hand cutting with chisel and hammer. Steam saws consisting of a thin blade of soft iron fed with small globules of chilled iron or a sand composed of crushed steel are used to some extent. Monolithic columns are in some instances turned on giant lathes, the cutting tools being revolving discs of steel. A planer with cutting discs of the same nature is sometimes used (see Fig. 12). Smooth surfaces for polishing are produced by grinding, the block being placed on a horizontally revolving iron bed, the cutting material being the chilled iron, sand or emery as the case may be; or, where the block is too large there is used a movable grinder such as is shown in Fig. 13. The necessary smooth surface having been produced, the polish is imparted by means of a revolving wheel covered with felt. This is kept wet and a white powder, known to the trade as "polishing putty" is sprinkled over the surface occasionally, the friction from the revolving wheel aided by the putty shortly producing the desired

results. An almost perfect surface is the first essential to the production of a good polish. Sandstones, limestones and marbles are sawn by the reciprocating blades of soft iron mentioned above, which are usually mounted several or many in a frame, an inch or more

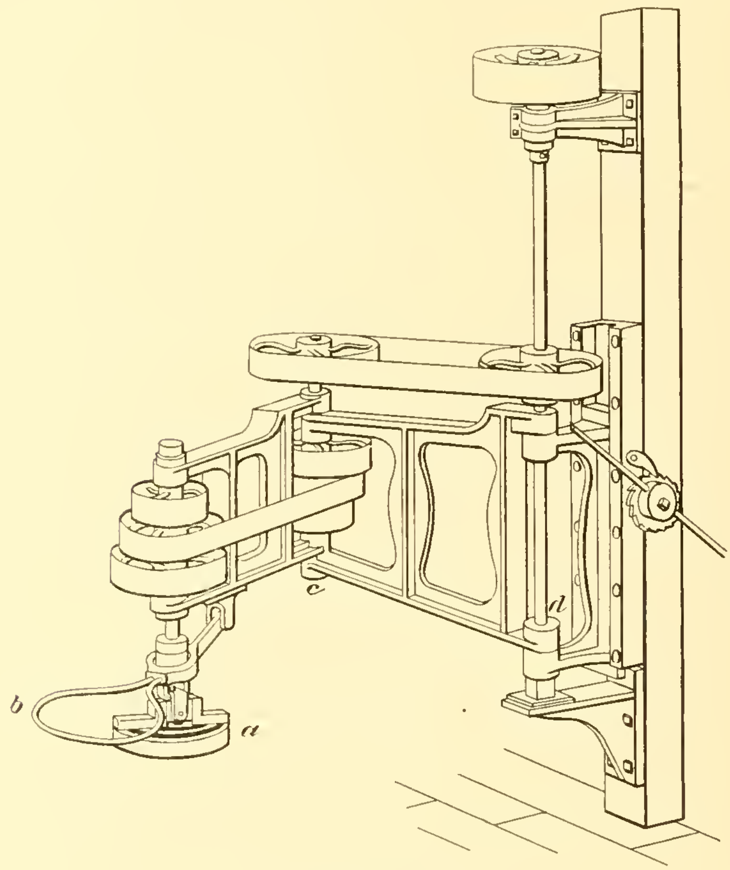


FIG 13.—Stone polisher.

apart according to the thickness of the slabs or blocks which are to be cut, the cutting material as before being sand or chilled iron. Sand is preferable when the material to be cut is not too hard, since not likely to stain the stone, through rusting. Moreover little particles of the iron or steel are likely to become imbedded in the stone

during the early stages of grinding and these breaking loose during the later stages, when the surface is nearly smooth, do much damage by scratching or else remain permanently imbedded to give rise to rust spots when the stone is exposed to moisture. These softer stones are also planed by machines operating on the same principles as those used in planing metals. A modification of the same machine is used in producing mouldings. Carved surfaces are still produced mainly by hand, hammer and chisel, though machines operating like miniature stream drills have been employed for this purpose.

Various forms of finish are applied to the surfaces of stones, and are called by names as a rule indicative of the means employed. A rock face finish is the natural fracture of the rock, scarcely touched by chisel. A pointed face is a rock face the inequalities of which have been reduced by a sharp pointed implement known as a point. A surface cut into parallel shallow grooves from a quarter to a half-inch in diameter, is known as a dove-surface. A tooth-chiseled surface is produced by means of a wide chisel, the cutting edge of which is toothed like a saw. Ax or pean hammered surfaces are produced by striking upon the surface, always in one direction, with heavy hammers, the cutting faces of which are reduced to an ax-like edge, the result being that the finished surface is covered with long parallel-lying lines and ridges. A patent hammer made up of thin plates of steel so bound together as to form a compound cutting edge is also used for this work.

It is well to call attention here to the fact that in material so inelastic as stone the result of the impact of such blows, however slight, on the surface, is to produce minute fractures parallel to the surface, which result in scaling. The scales thus loosened are, it may be, but slight and at first inconspicuous. Nevertheless the tenacity of the stone for a variable distance below the surface has been weakened, and here disintegration must first make itself apparent. Beyond doubt the most durable finish is a rockface, sawn or properly prepared polished surface, since in these the natural condition of the constituent minerals or granules remains undisturbed.

It may be stated here that all stone works more easily when newly

quarried than after seasoning, though this characteristic is more strongly marked in the sandstones and limestones than elsewhere.

Not only do stones harden through seasoning, but the rift and grain are often less pronounced, and dry seams and other defects become more pronounced. Hence it is always best to work up stone as soon after its removal from the quarry as possible. Indeed roofing slate, as every quarrier knows, cannot be split at all satisfactorily after the water has once dried out of it.

Relation of Maryland to other Producing Areas.

The same geological agencies which were instrumental in the forming and rendering accessible of so large a variety of stone in Maryland operated throughout almost the entire Eastern United States and were productive of very similar results. From Northern New England to Central Georgia, along the entire length and breadth of the Appalachian chain, conditions of sedimentation and uplift, of eruption and metamorphism were so similar, that a remarkable uniformity exists so far as regard to character of materials is concerned, though in quantity, accessibility and quality, there is often a very great diversity. It will be of interest as well as not unprofitable for us to devote some space to a consideration of the resources of the neighboring states, and to the conditions governing their output, since here, as in other business enterprises, competition is likely to play an important part in all other than purely local markets.

PRELIMINARY GENERALITIES.

The axis of disturbance, above repeatedly referred to, extends from Maine southeasterly, not parallel with the coast, but retreating gradually inward, until south of New York it is no longer accessible by tide-water communication. This is an important physiographic feature, since transportation by water is always cheaper than by rail. This is particularly the case with heavy and indestructible materials like stone. In Maine many of the quarries are either directly upon the coast or bordering along its numerous fiords and rivers. The

quarried materials, with scarcely any preliminary handling, can be placed directly upon schooners and carried to all the leading cities of the eastern United States without transshipment. Hence Maine and Massachusetts granites and Connecticut sandstones early came into use throughout the entire coastal area of the eastern United States and in some cases were even carried around Cape Horn to cities upon the western coast (Plate V, Fig. 2). Further than this Nature has, throughout the entire New England states and large portions of New York and Pennsylvania, greatly favored quarrying operations through the medium of the glacial ice sheet. This powerful erosive agent carried off the residuary products which result from years of rock decay and left the ledges of granite, slate, marble, or whatever they may have been, fresh and hard to the very surface. Throughout the entire region to the south of the extension of this sheet, it is only here and there that there is to be found a quarry not buried by rotten matter that must be removed by stripping before quarrying can be commenced. This latter fact is well known to Maryland quarriers, and is shown in the views of quarries given on Plates XVIII and XX.

KINDS OF STONE PRODUCED BY OTHER STATES.

In *Maine* there are in operation to-day only quarries of granite, gneiss and gabbro, and of roofing slate. Very many of the granite quarries lie so near the water's edge that cost of transportation is reduced to the mininum, and hence quarriers are enabled to compete with others, even in markets at a great distance. The roofing slates lie remote from water ways and only the general excellence of the materials enables them to compete with others beyond the state limit. The output of these materials for 1889 was: of granite 6,701,346 cubic feet valued at $2,225,839.00, and of slate 41,000 squares, valued at $201,500.00.

New Hampshire has only quarries of granite and gneiss that need be here considered. These are all dependent upon railroads for transportation, but the quality of some of the granites, notably those of Concord, enables them to compete successfully with others more

favorably situated. The entire output for the year 1889 was 2,822,-026 cubic feet, valued at $727,531.00.

Vermont produces a greater variety of materials than either of the above mentioned states, including granites, marbles and roofing slates, although few of the granites are of such a nature as to lead to their being transported beyond the state limits, so long as the transportation is limited wholly to railways. The marbles and roofing slates are, however, of such quality as to lead to their use, even under these adverse conditions, in nearly every state in the Union.

During 1889 the statistics of production of the three classes of stone mentioned above were as below: granite (and allied rocks) 1,073,936 cubic feet, valued at $581,870.00; marbles 1,068,305 cubic feet, valued at $2,169,560.00; roofing slates 236,350 squares, valued at $596,997.00.

The marble of Vermont, it should be stated, is, with the exception of the colored varieties of Mallett's Bay, almost wholly crystalline limestone and of such a nature as to make it better adapted for monumental and decorating work than general building, while those of Maryland are dolomites, and, so far as now developed, almost wholly building marbles.

Massachusetts. This state produces for other than local uses only granites, marbles and sandstones. With the exception of the granites which lie along the coast, as those of Gloucester, Rockport and Quincy, the transportation is wholly by rail. Nevertheless the quality of the stone, the early date at which the quarries were opened, and the energy of the operators has been such that they have been widely used, and in many cases to the entire exclusion of equally good material from close at hand. The marbles are crystalline granular dolomites and wholly of the building type, and on casual inspection are scarcely to be distinguished from those of Cockeysville, Maryland. Sandstones are produced only in the southern central part of the state, as near East Long Meadows, the stone bearing a general resemblance to that of Seneca Creek in Maryland, though perhaps of a warmer hue. Many of the granites, as those of Quincy, Dedham and Milford,

RED SANDSTONE.

SENECA, MONTGOMERY COUNTY.

are of a type quite lacking in other states. The output of the three classes during 1889 was as below, no statistics for marble being available: granite 9,587,996 cubic feet, valued at $2,503,503.00; and sandstone 1,967,179 cubic feet, valued at $649,097.00.

Rhode Island. Only the granites of this state need consideration from our present standpoint. Near Westerly are quarries of a fine, evenly textured stone of gray or sometimes pink color, that has come to be extensively utilized for monumental work in all our cities and towns. The transportation is both by rail and water, Westerly being at the extreme western border of the state, with direct rail communication to New York and Boston and but a few miles from Long Island Sound. The output of granite for the entire state for 1889 was 2,878,239 cubic feet, valued at $931,216.00.

Connecticut like Massachusetts produces granites, marbles and sandstones. The marbles like those of Massachusetts are white, crystalline granular, in part dolomites and in part limestones. The granites, with the exception of some coarsely variegated gneissoid rocks occurring at Stony Creek, are little used outside of the state. The sandstones, and especially those along the Connecticut River, as at Portland and Cromwell, are very extensively quarried and owing to the ready transportation facilities offered by the river, are extensively utilized in all the Eastern cities, and have even been sent around Cape Horn to San Francisco. These sandstones are brown Triassic stones of the same type as those of Seneca Creek and other points in Frederick county, Maryland, and it is only that they so lie as to offer exceptionally favorable facilities for quarrying and transshipment that the Maryland stone has not thus far proven a more successful competitor. The statistics for the state for 1889 so far as available are as follows: granite 3,835,704 cubic feet, valued at $1,061,202.00, and sandstone 2,821,430 cubic feet, valued at $120,061.00.

New York. This state, like Pennsylvania, yet to be noted, is so situated with reference to the Appalachian system, and comprises so large an area, that its resources are great and varied. Within its

borders are to be found quarries of granite and allied rocks, marbles, sandstones, quartzites and slate. The granites, of both red and gray colors, are eminently suited for building, decorative or monumental purposes. The quarries are, however, largely in the northern central part of the state and remote from waterways, so that the stones are little used for general building outside of the state. Dolomitic marbles, coarsely or granular crystalline in structure and utilized only for general building, occur in the southeastern counties of the state. These compare closely with those of Cockeysville in Maryland, and will compete with them on about even terms. In St. Lawrence county are other coarsely crystalline, gray building marbles, which are, however, little used beyond the state limits. Black, gray and variegated marbles suitable for interior decoration occur in the northern and eastern part of the state, but being of a type wholly distinct from any known to exist within the limits of Maryland, may for the present be omitted from consideration. Sandstones and quartzites, suited for building and flagging, occur in inexhaustible quantities widely distributed throughout almost the entire length and breadth of the state, some of the better known being the Potsdam quartzites of St. Lawrence county, the Medina sandstones of Monroe, Niagara and intermediate counties and the so-called "bluestone" or "flagstone" of Albany, Green and Ulster counties. The Potsdam stones are accessible by rail, and the water routes of the Great Lakes; the Medina, also, while the flagstones last named are largely within comparatively easy reach of the Hudson River. Hence all these stones are widely and for the most part favorably known. The slate producing areas are limited wholly to the extreme eastern portion of the state, Washington county alone being a constant producer. The material is of red or green color, and on this account does not enter into direct competition with that of Maryland.

The quarry statistics of the state for 1889 are as below:

Granite	1,515,511	cu. ft. valued at	$ 222,773.00
Marble	1,171,500	cu. ft.	354,197.00
Sandstone	6,490,406	cu. ft.	1,177,822.00
Slate	16,767	squares	81,726.00

New Jersey. This state produces only brown Triassic sandstones, similar to those of Frederick and Montgomery counties in Maryland, which need consideration here. The close proximity of the state to the leading markets, as of those of New York, Philadelphia, Baltimore and Washington renders it possible to transport the quarry product at comparatively low rates, even though such transportation must be made mainly by rail. The Triassic belt extends from the New York state line southwesterly to the Delaware River. The principal quarries are in Passaic, Essex, Hunterdon and Mercer counties. The stone resembles that of Connecticut perhaps more closely than that of Maryland, but nevertheless the general resemblance is so close that as a rule the selling price of the material will be the controlling item in deciding which shall be used.

According to the returns of the 11th census, some 6,010,212 cu. ft. of sandstone were produced during the year 1889, valued at $597,-309.00.

Delaware produces little in the way of building stone except for local use. Certain gabbros and gneisses have been quarried for purposes of rough construction, but do not need consideration here.

Pennsylvania. As noted above the quarry product of this state is large and varied. Singularly enough, however, there is little in the way of granitic rocks that need consideration. Good building marbles and serpentines occur in Montgomery and Chester counties and in both instances the stone so closely resembles that of Maryland that the price at which the material can be put upon the market must be the controlling factor of commercial importance. The Maryland quarries are nearest to the markets of Baltimore and Washington, but those of Pennsylvania to those of Philadelphia and New York. Brown Triassic sandstones, similar in a general way to those of Frederick and Montgomery counties, but of a more uniform brown hue, are quarried at Hummelstown in Dauphin county, and enormous quantities of gray and blue, gray thin bedded sandstones and "bluestones," used for general building and flagging, in Pike, Carbon, Luzerne, Wyoming and Susquehanna counties. With the exception

of the "Wyoming Valley" stone, as that of Wyoming county is commercially known, few of the latter find their way beyond the state limits. Blue-black roofing slates, such as must compete with those of Maryland, occur in the southwesterly part of the state, in Berks, Dauphin, Cumberland and Franklin counties, and also in enormous quantities in the northern parts of Northampton and Lehigh counties. For many years these deposits have been systematically worked, the product being used for roofing, billiard tables, sinks and school purposes all over the United States. The statistics given below will convey better than words some idea of the magnitude of the quarrying operations here carried on.

Granite 5,782,887 cubic feet, valued at $623,252.00;[1] marble, statistics not given; sandstone 19,119,357 cubic feet, valued at $1,942,-979.00; serpentine statistics not given; slate 476,038 squares, valued at $1,541,003.00.[2]

Virginia produces granites, sandstones and slates only, and as transportation of the quarry output is wholly by rail and there is little competition in the carrying trade, but little of the material finds its way into the general markets. The granites near Richmond have been used in some of the important buildings of Washington, and the red-brown Triassic sandstones from near Manassas are in demand for the construction of dwellings. The statistics of the state are given below:

Granite 1,073,936 cubic feet, valued at $581,870.00; sandstone 70,800 cubic feet, valued at $11,500.00; slate 30,457 squares, valued at $113,079.00.

North Carolina. With the possible exception of one granite and a few Triassic sandstones this state at present produces nothing finding a market beyond its limits. There are, it is true, in the western half, granites in abundance, and several promising beds of marble, but

[1] It is difficult to say what is included here under the name of granite, since there is scarcely a quarry of true granite within the state limits. Presumably it includes everything not otherwise classified.

[2] Some $370,723 worth used for other purposes, in addition.

so far they have been so little worked that nothing definite can be said regarding them. In the southern central part of the state are beds of brown sandstone, the equivalents of the Triassic beds in the states to the northeast. These have been worked spasmodically and the quarry product shipped to coastal cities including Baltimore and Washington. The total output in 1889 so far as statistics are available is as follows:

Granite 708,267 cubic feet, valued at $146,627.00; sandstone 50,000 cubic feet, valued at $12,000.00.

South Carolina. Although there is an abundance of granite in Fairfield, Richland, Newberry, Lexington, Edgefield and Aiken counties none of the material finds its way beyond the state limits. Material to the value of $55,320.00 is stated to have been quarried in 1896.

Georgia. This state has several quarries of granite, and in its northern portion extensive deposits of coarse crystalline granular building marble. This last named is coming into very general use for building, monumental and interior work, even in cities as far north as Boston. Its consideration is therefore important here. A deep dark gray, nearly black roofing slate also occurs at Rockmart in Polk county which is finding a slight market outside of the state. The statistics for 1889 as given are as below:

Granite 2,425,622 cubic feet, valued at $752,481.00; slate 3,050 square feet, valued at $14,850.00; marble 25,000 square feet, valued at $196,250.00.

The quarries, it should be noted, are all remote from waterways, and transportation is therefore limited to railroads.

Tennessee. In this state only the marbles need consideration from our present standpoint, and these only on the supposition that at some time the proposition may be entertained of opening up quarries in the colored marbles of Carroll and Frederick counties. The Tennessee stones are dark chocolate and white, fossiliferous, and gray and pink crystalline granular limestones. The latter are used both for general building and interior work and the first for interior work only.

There are in addition to the stones above mentioned, certain others from more remote sources which, owing to their peculiar lithological natures, are to be found in all the principal markets of the country. The so-called Bedford stone or Bedford Oolites and the Berea sandstones are of this type. The first mentioned of these is a very pure limestone but differs from those of the states above mentioned in that it is made up almost wholly of minute rounded or oval concretionary grains, often of almost microscopic dimensions. It is of a very light grayish color, sometimes almost buff, soft, very readily workable, and occurs in nearly horizontally lying beds covering a large extent of country. It can therefore be quarried and worked very cheaply, and as it is, on the whole, of a pleasing color and fairly durable nature, it finds a ready market in most of our larger cities.

The second stone mentioned, that of Berea, Ohio, is a fine grained sandstone belonging to the Waverly series of the carboniferous formations. This rock is an ideal " freestone " in so far as this term refers to working qualities, since its even granular structure and not too pronounced lamination permit it to be worked with the greatest facility in any direction. The prevailing colors are light gray to buff, and though from the standpoint of durability no better, nor perhaps so good as many stones nearer at hand, it too, on account of its cheapness and color, finds its way into markets at such a distance as would cause it to be excluded by cost of transportation under less favorable conditions.

Reference in passing should also be made to such stones as are brought to our markets from foreign sources. As a very general rule it may be stated that the stones thus introduced are of a different type, so far as color and texture are concerned, from those produced locally, and that they are brought in in response to the public demand for a greater variety. This is not, however, invariably the case since, as is the case with certain of the Italian marbles, easy quarrying facilities and cheapness of labor enable the producers to put the stone upon the American market at lower rates than the domestic product, notwithstanding the discrepancies of distance and consequent cost of transportation. Naturally a large proportion of the imported mate-

rials are marbles since, aside from being most expensive, such are used very largely in the form of thin slabs for veneering, rather than in solid blocks of masonry. There are, however, a few stones of the granitic type, used more particularly for monumental work, which find their way into our markets in considerable quantities. Of the marbles which come to our market we need mention more particularly the deep red and yellow often brecciated varieties from Algeria, the so-called Numidian marbles; the white, blue-gray, often veined, black and yellow mottled varieties from Northern Italy, particularly from Carrara and Sienna; and the green or so-called Verd-antique marbles (serpentines) from Genoa and near Prato. Stones very similar to these last are found in various parts of the United States, particularly in Vermont, but are excluded from competition by the high prices of labor prevalent in America. Stones of this same general nature, but of more uniform green color, occur in Maryland and adjacent portions of Pennsylvania, but though from time to time quarried, have never been worked upon a scale sufficient to exclude the imported material even were the character of the marble the same. Other marbles than those mentioned, that come to us from abroad, are the so-called Formosa and Bougard marbles of Germany and the Griottes of France.

Nearly all of the granitic rocks which reach the American markets from abroad are what are known as monumental stones. With the exception of those that are introduced from nearby sources, as New Brunswick, the cost of transportation is too great to warrant the bringing in of materials that must be sold sufficiently cheap to compete with the native product in ordinary structural work. Among the more important of the granites introduced are the red and gray so-called Scotch granites, from near Peterhead in Aberdeenshire, Scotland. A coarse, porphyritic stone, showing large pink orthoclase crystals in a gray ground mass comes from Shap in Northern England. Of greater interest on account of their beauty are a few types of granitic rocks that have of late been introduced into our markets from near Finspong in Southern Sweden. One of these is a coarse granular aggregate of deep red feldspars and opalescent quartz, forming when

polished a strikingly beautiful stone for monumental work, and quite unlike anything now produced elsewhere. There have been also introduced from this region coarse feldspathic rocks belonging to the syenitic type, of a dark blue gray color, sometimes almost black, which are of particular interest on account of the iridescent character of the feldspars. They are quite similar in general appearance to the so-called labradorite rock from Labrador, and well adapted to interior decoration work.

Resumé. We have thus enumerated briefly the possible resources of the coastal states with which Maryland may be profitably compared. It is apparent that the future of the quarry industry must depend then, not so much on the kind of materials since similar kinds are to be found elsewhere, as on accessibility to certain markets, and perhaps an ability to quarry at such rates as will enable her to compete with others, more favorably situated, at a distance. Although placed at a disadvantage so far as relates to actual quarrying through the mantle of decomposition product that covers so much of the outcrops, and through a lack of water transportation, the state is favored by a climate that will permit work out of doors for a much longer period than is possible in the North. Differences in price of labor is also an item which may be taken into consideration.

WEATHERING OF BUILDING STONE.

All stones, as they lie at and near the surface of the ground, are subjected to a number of agencies, in part physical and in part chemical, which result in a more or less complete disintegration, decomposition, or it may be temporary induration of the materials acted upon. Since these changes are due to atmospheric agencies, to the expansion and contraction of ordinary temperatures and to hydration, solution and oxidation brought about through meteoric waters, they are all grouped commonly under the general name of weathering.

Rock-weathering has been going on ever since the first rocks appeared above the ocean level. To its destructive powers we are indebted for not merely the soil, but for the materials which make up the many thousands of feet of conglomerate, sandstone, shale and slate which occupy so large a part of the earth's surface.

The effects of this weathering are to-day visible and the progressive stages readily traceable in many parts of Maryland and in other of the states to the southward.

The views given in Plate XIV show the manner of weathering quite characteristic of granite rocks, particularly where such are traversed by numerous joints. The water percolating over the surface and filtering downward through the joints, brings about a disintegration and decomposition, whereby the sound rock gives way to sand, gravel and clay, all very likely discolored by iron oxides set free through decomposition from the micas and other ferruginous silicates. Since on joint-blocks this weathering, which may well be compared with the rotting of an organic body, would naturally take place most rapidly on sharp edges and corners, so these salients become gradually rounded, and an oval, bowlder-like mass of varying size results, as shown in the Plate XIV. It is thus that there have been formed from the dark colored igneous rocks the so-called " nigger-heads " so common in many parts of the state. It is not necessary to here go into a detailed discussion of the processes and resultant products of rock-weathering. Such a treatment of the matter the writer has given elsewhere.[1] It will be sufficient here to say, that the results of prolonged weathering of granitic and allied rocks is a ferruginous sand and clay; of sandstones a sand, and of argillite and limestones a ferruginous clay. In some instances weathering may be productive of a local induration causing soft and friable stones to become harder and more durable, though this is far from being a general and widespread phenomenon. In many instances the preliminary stages of weathering are manifested by a change of color, due to the whitening of the feldspathic constituent, or, as a rule, to the oxidation of included sulphides of iron (pyrite and marcasite) or to a like change in ferrous carbonates or iron-rich silicates. Such changes may or may not be detrimental, according to local conditions. Obviously a yellow or brown stain from oxidizing pyrite on a light surface like that of marble, is unsightly. In many lime and sandstones, however, the ferruginous constituents are so evenly disseminated that the stone,

[1] Rocks, Rock-weathering and Soils, the Macmillan Company, New York, 1897.

on exposure, assumes a uniformly buff or yellowish hue, which is known, commonly, as "mellowing," and which is not at all undesirable. Changes of this kind are limited mainly to light colored sedimentary rocks, and such as have been quarried from below the permanent water level. This for the reason that exposure in the quarry bed above the water level has already brought about the oxidation and color change, so that when quarried and placed in the walls of a building no further change takes place.

But the effects noted above are mainly the products, it may be of geological periods, of years so many as to be quite incomprehensible from a human standpoint. We need consider here only those effects which may be brought about by these same agencies operating throughout a few score or perhaps hundreds of years.

Stone taken from the ground and exposed in the walls of a building is subject to two agencies both destructive and tending toward disintegration. As already noted, the one is physical and the other chemical. During a hot summer day, stones exposed to the direct rays of the sun may become, on the immediate surface, heated to a temperature of even 150° Fahr. On the going down of the sun, a gradual cooling takes place. In the coldest weather of winter the temperature may sink as low as zero. Now, as it is well known, heat causes expansion and cold contraction. Let the reader then picture to himself what here takes place. The mass of the stone is made up of an admixture of mineral particles without definite order of arrangement and all practically in actual contact with one another. As the temperatures rise each mineral expands ever so slightly and crowds against its neighbor; but aside from the unequal expansion of minerals of different species, the process is further complicated by their tendency to expand unequally along their different crystallographic axes. So all through that portion of the stone thus warmed there arises a condition of very unequal tension, which is naturally greater the greater the amount of heat. As temperatures fall a corresponding contraction takes place; but in material so granular and inelastic as stone the particles do not again recover exactly their original relative positions. Minute rifts are opened, not merely between the granules,

but also along the cleavage planes of the minerals themselves, so that in time all cohesion is lost and the stone becomes so weak as to fall away to the condition of sand, or as is more commonly the case, absorbs so large an amount of water that when freezing ensues, disintegration results. Since any stone will absorb the most water along the bedding or lamination planes, and since too the stone is weakest, the cohesion of the particles least, along these planes, so it follows that laminated stones, like sandstones, often show signs of scaling on their outer surfaces even after an exposure of but a few years in the walls of a building. It is this form of disintegration which is so conspicuous and unfortunate a feature in many buildings constructed of brown, laminated sandstone, in Baltimore and other cities. Such a tendency may be largely overcome by laying this stone on its natural bed, but any stone whatever its nature is more or less susceptible. Inasmuch as stones are but poor conductors of heat, that is, as the heat penetrates but slowly, and to but slight depths, such a form of disintegration is limited to the immediate surface. Where, however, the disintegrated material is removed so soon as formed, the process may go on indefinitely until a finely carved front or cornice may be entirely ruined.

It follows from the above that, other things being equal, a stone in which the various mineral particles are closely interknit will be more durable than one of granular structure.

One of the most serious of the destructive agencies to which stone in the walls of a building are subjected is the freezing of absorbed water. All stone as they lie in the ground contain more or less moisture or *quarry water*, as it is called, which in time dries out after the stone is quarried. More water is however likely to be absorbed on exposure to rains, and since water in freezing exerts an expansive force equal to some 150 tons to the square foot it may be readily understood that if the amount of moisture contained in the pores of a stone is at all large, serious disintegration may result. It is to this cause that is largely due, as already noted, the scaling and crumbling of the brown sandstone so commonly used in house construction throughout the Eastern United States. Other things being equal again, a stone

possessing low absorptive power will be more durable in moist, temperate and frigid climates than one that will absorb a large amount. Figures showing the relative amount of water absorbed by stones of various kinds are given in the following table.

ABSORPTION TESTS I.

Kind of Stone.	Wgt. after drying 24 hours at 212 F.	Wgt. after immersion 24 hours in water. Grams.	Gain in weight. Grams.	Percentage of absorption.
Marble, Cockeysville,	367.15	367.93	0.78	0.212
" "	367.07	367.86	0.79	0.215
Sandstone, Seneca,	313.35	321.28	7.93	2.530
" "	313.75	321.18	7.43	2.368
Granite, Port Deposit,	351.33	352.22	0.89	0.253
" "	341.34	342.00	0.66	0.196
Granite, Woodstock,	340.43	341.31	0.88	0.258
" "	340.45	341.24	0.79	0.232
Gneiss, Baltimore,	354.37	355.07	0.70	0.197
" "	323.36	326.97	3.61	1.116
Sandstone, Taneytown,	320.22	324.05	3.83	1.196
Quartzite, Emmitsburg,	347.58	347.87	0.29	0.083

ABSORPTION TESTS II.

	Wgt. air dry. Grams.	Wgt. after immersion one hour. Grams.	Wgt. after immersion one day. Grams.	Wgt. after immersion one week. Grams.	Gain in wgt. Grams.	Percentage of absorption.
Marble, Cockeysville,	367.25	367.30	367.60	367.60	0.35	0.09
Sandstone, Seneca,	1002.70	1007.70	1010.80	1011.70	8.05	0.07
Granite, Woodstock,	345.00	345.50	345.50	345.55	0.05	nil
Gneiss, Baltimore,	350.70	350.65	350.70	350.67	——	nil
Sandstone, Taneytown,	329.60	330.50	330.90	331.55	1.95	0.59
Quartzite, Emmitsburg,	344.50	344.50	344.50	344.85	0.35	0.10

In the second set of experiments which were conducted by Dr. Mathews, the blocks were all of the same size (two inches cube) as those of the first set, except in the case of the Seneca sandstone, where a block four inches square and one and a half inches thick was employed. The weighings were made after the blocks had been swabbed until no glistening water remained. These tests show that little water is taken up by the specimens beyond that carried after remaining over

a year in the warm air of an office. The weather during the experimenting was warm (85°-95° F.), and the humidity was approximately seventy per cent.

The water which comes to the earth in rainfalls is never absolutely pure, but contains a variety of mechanically and chemically admixed impurities. Among the chemically admixed, or dissolved impurities, which are the only ones that need here be considered, carbonic acid is the most widespread and abundant, while in smaller amounts and particularly near large cities there may be traces of hydrochloric and sulphuric acids. These all are capable of exerting a solvent action on the material composing building stone, particularly on lime carbonate. The amount of material that will be dissolved during a single shower may be infinitesimal, or during a year scarcely appreciable. Yet there are many stones, particularly those composed of pure lime carbonate (limestones), or of siliceous granules cemented by lime carbonate, which in time suffer severely. The roughened surface and loss of polish seen so frequently on marble tombstones and exterior work of any kind is usually due to this solvent action of rain water and its dissolved acids.

The adaptability of a stone for structural purposes depends then, in no small degree, upon its weathering qualities, that is to say upon its power to withstand for centuries even, exposure in the walls of a building, without serious discoloration, disintegration or solution. Let us now take into consideration these weathering qualities as displayed by the various types of rocks, although a full discussion of the subject must be left for more comprehensive treatises.[1]

Granites and gneisses possessing very low ratios of absorption (see table above) and being made up so largely of silica and silicate minerals, are very little affected by freezing and solution. The chief causes of disintegration with rocks of this class, are temperature changes, such as produce granulation. Aside from a weakening of the cohesion power between the individual constituents, the feldspars may split up along cleavage lines, and a disintegration follows which may be sufficiently evident to cause small spawls to fall along the

[1] See Rocks, Rock-weathering and Soils, the Macmillan Company, New York, and Stones for Building and Decoration, Wiley and Sons, New York.

joints between the blocks, or perhaps to ruin fine carvings. In some instances deleterious minerals like pyrite may be present in sufficient quantity to cause unsightly discoloration.

All things considered, a fine grained homogeneous rock will be found more durable than one that is of coarser grain. Also a rock in which the individual particles are closely interknit, dovetailed together, as it were, will resist disintegration longer than one that is of a granular structure at the start.

Serpentines are likewise only slightly absorptive and when homogeneous little affected by solution. Nearly all serpentines of such quality as to be used as verdantique marble contain, however, veins and spots of calcite, dolomite or magnesite, and many dry seams. Such rocks, therefore, weather unevenly, lose their polish, and may shortly crack and split along these dry seams when exposed to the weather. These marbles should then be used only where protected from the weather. Crystalline limestones and dolomites (marbles) are extremely variable in their weathering qualities, are likely to carry pyrite, and great care needs always be exercised in their selection. A limestone marble, *i. e.* one composed essentially of lime carbonate, is likely in time to suffer from solution whereby corners become rounded, surfaces roughened and perhaps inscriptions obliterated. The mechanical agencies are here also operative as in granite, so that, as a rule, a stone of this class is less durable than a good granite. The pure white stones are, as a rule, more granular and weaker than the gray and blue gray. Dolomites being less soluble than limestones might at first thought seem promising of greater durability than the limestones. Unfortunately this is not altogether the case, since such stones often possess a more granular structure than do limestones, and hence suffer more from disintegration. Indeed a dolomitic marble can, not infrequently, be distinguished from one of pure limestone, simply from the way it weathers in the natural outcrop. In the case of the dolomite, the surface of the outcrop may be found covered here and there with a sand composed of angular particles which results merely from the mechanical disaggregation of the stone, while in the second case the stone loses almost wholly by

solution, and we find it passing superficially into a clay without the production of sand.

The light colors characteristic of most marbles render iron stains peculiarly objectionable, and as pyrite is a very common constituent of such rocks, much care is necessitated in its selection. The ordinary unmetamorphosed limestones, like the deep blue-gray varieties from the Trenton formation are scarcely at all absorptive, and weather fairly well, but their sombre colors are something of a drawback.

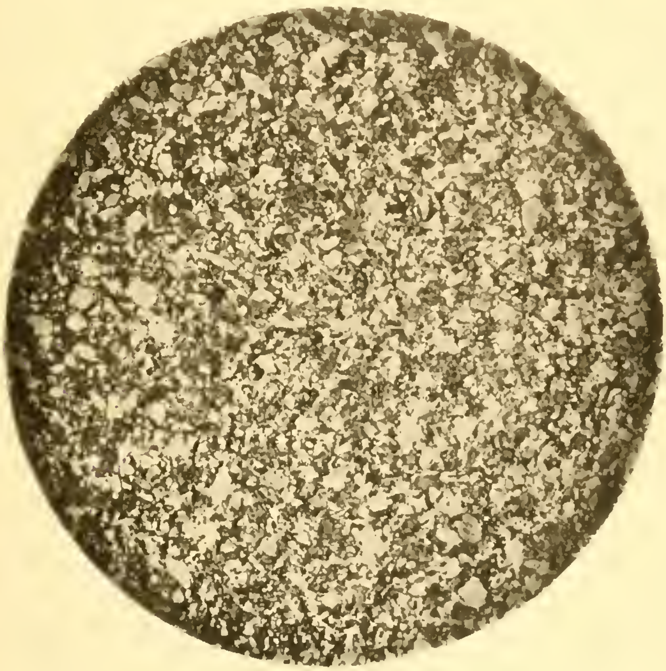


FIG. 14.—Photomicrograph of Seneca Sandstone (magnified ten diameters).

Sandstones, on account of the widely varying character of the materials of which they are made up, variation in texture, degrees of porosity, etc., are perhaps as a whole more variable in their weathering qualities than any other class of rocks. In order to fully appreciate this variability, we must remember that we have to do here with what are but beds of indurated sand; that these stones are made up of sand

particles held together by simply being closely compacted by finer material, or by means of a cement composed of lime carbonate, iron oxides or silica (see Fig. 14). Where the sand is loosely compacted, or the sand granules are interspersed with much finer, clayey matter, the stone will absorb comparatively large amounts of water and is likely to become injured on freezing. Where the cementing matter is carbonate of lime, rain water trickling over the surface is likely to remove it in solution, leaving the stone to fall away, superficially, to the condition of sand once more. Ferruginous cements are likewise slightly affected, though in a much less degree. The siliceous cement is least affected of all, and provided the amount of induration be the same, a purely siliceous sandstone, cemented by a siliceous cement, is one of the most indestructible of building materials.

Many sandstones have a distinctly laminated structure; that is, their particles are laid down in parallel layers, differing somewhat in size, color and degrees of compactness. The result is that some layers will absorb more water than others and the rock will undergo a splitting up into thin flakes. When such a rock is stood on edge in the walls of a building and the water filters down along these porous layers and there freezes, serious results follow, particularly when the stone is carved. Pyrite is a common constituent of sandstones, particularly the gray varieties, and is likely to produce staining. Its presence needs to be looked for with care. A fine-grained sandstone is often fully as absorptive as one that is coarse, and fully as likely to injure from freezing. A ratio of absorption of more than 4 per cent by weight must be regarded as unfavorable.

Roofing slates or argillites represent as a rule the indurated and otherwise changed argillaceous products of the weathering, or rotting as we might say, of pre-existing rocks. They are in short made up from the most indestructible of natural materials, and on first thought might themselves seem indestructible. Unfortunately those capable of being split sufficiently thin for roofing purposes are not in all cases indestructible, nor are they equally resisting in all parts. In nearly all slates there are to be found dark colored bands or ribbons, containing deleterious minerals like pyrite or marcasite, which are less

durable than are the other portions. Moreover the exposed position of slates, when on a roof, is such as to try to the utmost their lasting qualities.

It is here that the extremes of temperature are greatest and the acid action of rains most manifest. It is little to be wondered at therefore that in time the slates become brittle and break, or at least crack, a condition of affairs soon indicated by leaking. A slight fading in color is also a not uncommon feature of many slates, the exact cause of which does not seem to be yet fully apparent.

Methods of Testing Building Stone.

How to ascertain by any series of tests that can be performed in a laboratory the durability or general suitability for construction of any stone is a problem with which builders have long struggled and which is yet far from solution.

In order to appreciate the difficulty in the problem, let us briefly recapitulate.

Stone in the walls of a building is exposed to the chemical action of the atmosphere, the physical action of temperature changes and to the crushing and shearing forces incidental to its position in the wall. Satisfactory tests, then, must show the ability of the stone to withstand to-day any of the agencies enumerated above, and must also indicate its ability to withstand them after years of exposure.

A stone which to-day will withstand effectively any of the tests which can be applied may, through the prolonged action of external agencies, become so weakened as to be valueless or so discolored as to be unsightly.

In this chapter it is proposed to give a general summary of the tests which have thus far been applied, to show in how far they are successful, and to make such suggestions as seem pertinent to the subject. It will not be necessary to give in full all the details of these tests, as they have from time to time been made. It will be sufficient, rather, to refer only to such as are historically interesting or of value on account of the results they may have yielded.

(1) Tests to ascertain permanence of color. The change of color in a rock, on exposure in a building, is due mainly to a change in the

form of combination of the iron. Rocks taken from below the water level often carry iron in the form of protoxide carbonate ($Fe\ CO_3$) or pyrite ($Fe\ S_2$). Either on exposure to the air is likely to become oxidized as noted under the head of weathering. The tests that can be applied in the laboratory are made (1st) to ascertain the presence of sulphur, indicating pyrite, and (2nd) the effects of an artificial atmosphere in accelerating oxidation.

The following is the method for this last mentioned test as adopted by Prof. J. A. Dodge.[1]

The specimens tested were rectangular in outline, and from an inch to an inch and a half in diameter. These were dried in a water bath (temp. 212° F.) till all the absorbed moisture was expelled, cooled and weighed. They were then placed upon a set of glass shelves standing in a porcelain pan containing strong muriatic (hydrochloric) acid.

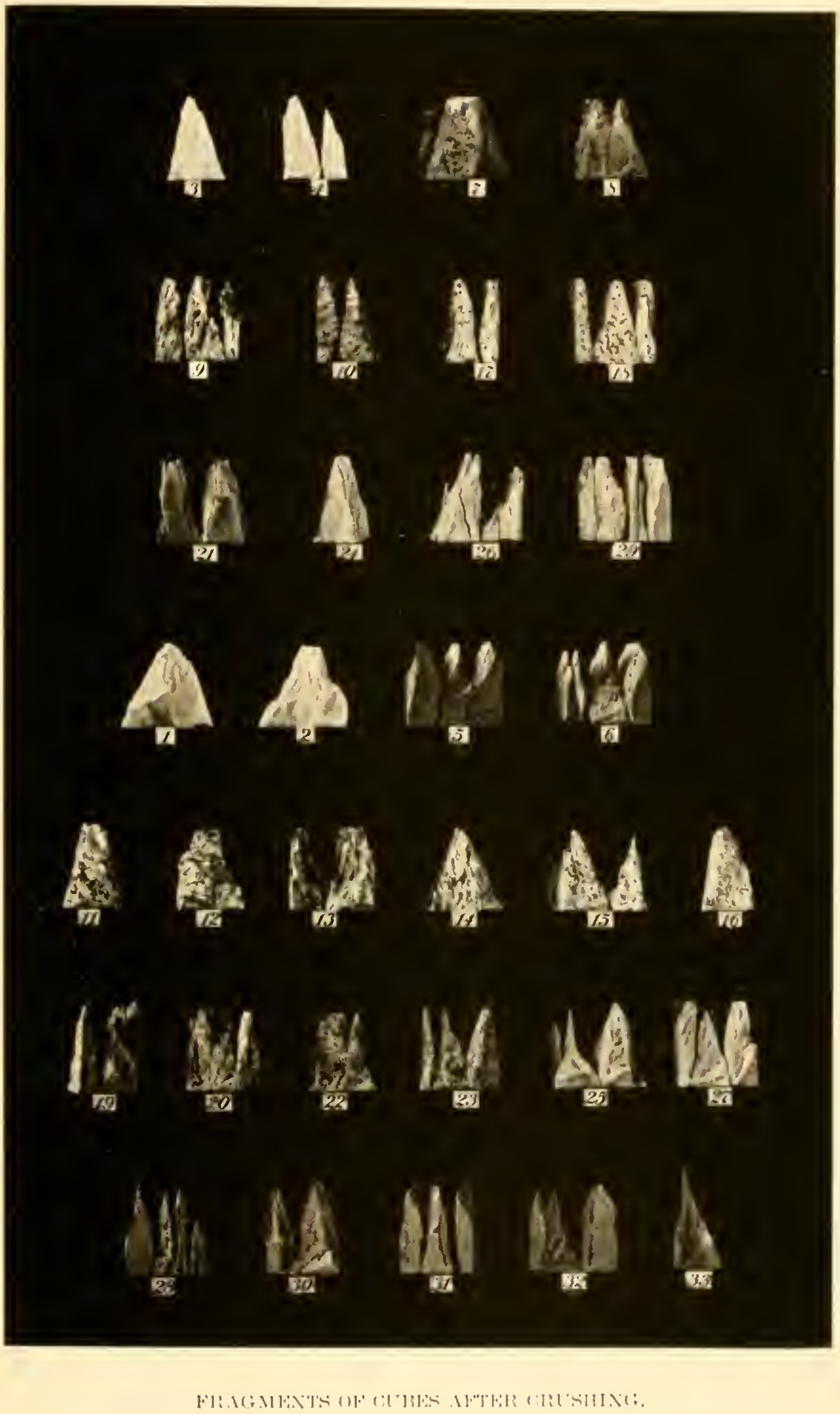
An open bottle containing nitric acid, and one containing hydrochloric acid and black oxide of manganese were placed close by, and the whole covered by a bell glass, forming an air-tight chamber. The fumes from the acids, together with the chlorine fumes from the manganese and hydrochloric acid, filled the chamber and exercised a powerful corrosive and oxidizing effect on the samples. After a period of seven weeks the stones were removed and washed, and the change in color, if any, noted. A similar series of tests was made by Prof. A. Wendell Jackson in 1887 on California building stones,[2] and the efficiency of the method seems fairly well established.

(2) Tests to ascertain resistance to corrosion. The question to be settled here is one relating chiefly to calcareous rocks, to limestones and marbles, or to sandstones containing a calcareous cement. The most satisfactory method available, is apparently that of Prof. Dodge, given in the publication above referred to, which is as follows:

A set of pieces of essentially the same size and shape as those used in the last mentioned tests were selected and dried and weighed in the same manner. These were then suspended by strings in a glass

[1] Final Report Geological and Natural History Survey of Minnesota, vol. i, 1872-82 (1884), p. 185.

[2] Seventh Ann. Report State Mineralogist of Cal., 1887 (1888), p. 205.



FRAGMENTS OF CUBES AFTER CRUSHING.

vessel of water, not in contact with one another, and a stream of carbonic acid gas was run through the water for several hours at short intervals, so as to keep the water pretty well saturated. The gas was washed before entering the vessel containing the stones, and the water in the vessel was changed every few days by means of a siphon. The action was continued for a period of six weeks, when the specimens were removed, washed in pure water, dried and weighed. The difference between the first and second weighing indicated the amount of material dissolved by the carbonic acid water. In the case of some limestones this was found to be over 1 per cent, though as a rule much less, and in the case of some granites so small as to be scarcely appreciable.

(3) Tests to ascertain resistance to abrasion. Tests of this nature are necessary only in cases where, as in steps and walks, the material is subject to the friction of feet, or where as in dams and breakwaters, it is subject to the action of running water and waves. In some instances it is possible that stones may be so situated as to be subjected to the action of windblown sand. In the selection of Belgian blocks for street pavements, it is naturally an important matter.

The resistance to wear, it may be stated, depends not more, perhaps even less, upon the actual hardness of the constituent particles of a stone, than upon the firmness with which they adhere to one another. This is well illustrated in the case of many sandstones, which though made up of the hard and difficultly destructible mineral quartz, are so friable as to be practically worthless. In making a series of tests of this nature, it is well to consider the uniform as well as actual hardness of the stone. Many stones wear unevenly, owing to their unequal hardness in various parts, and are even more objectionable than though uniformly soft throughout. The serpentinous steatite used many years ago for steps and sills in Philadelphia wore very unevenly owing to the superior hardness of the serpentine over the steatite, causing the former in time to stand out like knots in decaying logs. The power of any stone to resist abrasion can in the writer's belief, and as he has elsewhere[1] stated, be ascertained by observing the manner in which it works under the chisel.

[1] Stones for Building and Decoration. 2nd Ed., p. 415.

Resistance to the action of windblown sand could readily be ascertained by subjecting prepared samples to the action of an artificial sandblast such as is used in the Tilghman process of stone carving. A fairly accurate idea of the resistance to actual wear can be obtained by the rate at which the samples can be ground down on a common grinding bed. It is difficult to perfect this method, since so much depends on the weight applied and the constancy of the supply of emery, sand or whatever may be the cutting medium.

(4) Tests to ascertain the absorptive powers. These tests have a direct bearing upon those which are to follow, since it is largely through freezing of absorbed water that cold produces disintegration. The test of the absorptive powers is therefore one of the most important, and for a single test perhaps the most conclusive of any, as the writer has also elsewhere stated.[1] For reasons noted below it cannot be relied upon altogether.

There are two absorptive tests commonly made; the one to determine the absorption of moisture from a damp atmosphere, and the other the amount of absorption of water through actual soaking. Of the two the last is by far the more important.

The method of determining the absorption from a damp atmosphere as carried out by Prof. Dodge[2] is as follows:

The samples of stone were placed in the cells of a hot-water bath for several days, to expel their hygroscopic moisture, after which they were allowed to cool in desiccators, over sulphuric acid, and weighed. They were then placed upon a set of glass shelves standing in a pan of water, and a tight cylinder was inserted over the shelves, the mouth of the cylinder being sealed by the water, after the manner of a gas holder. The apparatus remained thus in a room the temperature of which was pretty uniform (from 60° to 70° Fahrenheit) for seven weeks, the water being replenished from time to time so as to maintain a constant closure of the cylinder. The stones were then removed to bell-jars in which they were supported over water, and thus taken to the balance and weighed. The samples submitted to this test were somewhat larger than those used for making the determination of specific gravity. They had an average weight of about 70 grammes,

[1] Op. cit., p. 439.

[2] Op. cit., p. 185.

and were roughly shaped. The minimum absorption of moisture .03 per cent of the weight of the stone, is so small in amount as to be practically nothing. The maximum 3.94 per cent of the weight of the stone seems quite considerable. It seems probable that, in the atmosphere saturated with moisture in which they were kept for seven weeks, some of the stones absorbed all the moisture they were capable of taking up, while others by a longer exposure to the same conditions would have shown still higher figures.

In determining the amount of absorption by soaking it is best to have the specimens as nearly rectangular as possible, with faces ground smooth, and for purposes of comparison as well as for possible subsequent use in other tests it is well to have them approximately in the form of 2-inch. cubes. These should be thoroughly dried and weighed, as in the tests previously mentioned and placed in a porcelain dish with sufficient water to cover them and allowed to stand until fully saturated—say a period of 3 or 4 days at least. The cubes should then be carefully removed, the water absorbed from the immediate surface by means of blotting or any form of bibulous paper, and then weighed. The drying and weighing should be accomplished with as little delay as possible, to avoid loss by evaporation. The increase in weight of the cubes is of course due to the water absorbed, and the percentages can thus be readily calculated. The results of a few tests of this nature are given on p. 91. As here shown, and as an almost universal rule, the sandstones are the most absorptive. It may be said further, that the absorption takes place most rapidly and in the largest amounts along the bedding planes. While the absorption of more than 3 or 4 per cent of water is a matter that can as a rule be regarded as detrimental, still it does not necessarily follow that such a stone will suffer most on freezing. This for the reason that a coarsely porous stone will dry more quickly than one of finer grain and moreover the size and shape of the interstitial cavities is such that the expansive action of freezing water finds relief without forcing apart the granules as noted below. It is sufficient to note here that a high rate of absorption is more detrimental to a fine than a coarse grained stone, and also that experiment has indicated that such

stones are weaker, will crush under less load, when saturated with water than when dry.

(5) Tests to ascertain resistance to freezing. The power of a stone to resist the action of frost is naturally largely dependent upon its absorptive qualities, as noted above, since it is the freezing of the absorbed moisture that produces disintegration. It has been shown that water passing from the liquid to the solid state, that is to the condition of ice expands in the proportion of 100 to 109. That is to say, an amount of water occupying 100 cubic inches before freezing must occupy 109 cubic inches after. The pressure exerted by this expansion is equal to 150 tons for each square inch of surface. Provided then the interstices of a stone are filled with water, which there freezes, it is easy to see that if there is no other way of relief, the stone must be sadly disrupted. Abundant evidences of this are to be found in any sandstone quarry that has been closed during the winter months without protection. That the result is not more marked than it is, is due to the fact that relief is found in the expansion outward through the pores of the stone. It is for this reason that a coarsely porous stone will often stand a freezing test better than one that is of fine grain, the expansive force finding relief outward through the larger pores.

The importance of the freezing test was early recognized, and several methods have been devised for making such in the laboratory.

Obviously, the best method to pursue is that of nature, and to actually submit the samples to repeated freezings and thawings. Unfortunately this can not at all times be readily done, and moreover nature's methods are sometimes slow, so that other schemes have been proposed with a view of showing the *relative* rather than the actual powers of resistance of different stones. Perhaps the best known method of determining the resisting power of stones is that proposed by Brard which consists in saturating the stone with a solution of sulphate of soda which on crystallizing expands as does water on passing into the condition of ice. A modification of Brard's original process was used by Mr. C. G. Page with reference to the selection of material for the Smithsonian Institution building in Washington.[1]

[1] See Hints on Public Architecture, p. 119, by R. D. Owen, also Stones for Building and Decoration, p. 439.

The process as carried on by Mr. Page consisted in boiling a carefully prepared and weighed cube, for half an hour, in a saturated solution of the sulphate, and then allowing it to dry, during which process the absorbed salt crystallized and expanded. Although the results were found to be not in all cases quite reliable, and evidence was deduced to the effect that the boiling salt solution exercised a chemical as well as mechanical action, still they are not without interest and may be given in tabular form as below.

Materials.	Specific gravity.	Loss in grains.
Marble, close-grained, Maryland	2.834	0.19
Marble, coarse "alum stone," Baltimore County, Maryland	2.857	0.50
Marble, blue, Maryland	2.613	0.34
Sandstone, coarse, Portland, Connecticut	..	14.36
Sandstone, fine, Portland, Connecticut	2.583	24.93
Sandstone, red, Seneca Creek, Maryland	2.672	0.70
Sandstone, dove-colored, Seneca Creek, Maryland	2.486	1.78
Sandstone, Little Falls, New Jersey	..	1.58
Sandstone, Little Falls, New Jersey	2.482	0.62
Sandstone, coarse, Nova Scotia	2.518	2.16
Sandstone, dark, coarse, Seneca Aqueduct, Peters's quarry	..	5.60
Sandstone, Acquia Creek, Virginia	2.230	18.60
Sandstone, 4 miles above Peters's quarry, Maryland	..	0.58
Sandstone, Beaver Dam quarry, Maryland	..	1.72
Granite, Port Deposit, Maryland	2.609	5.05
Marble, close-grained, Montgomery County, Pennsylvania	2.727	0.35
Limestone, blue, Montgomery County, Pennsylvania	2.699	0.28
Granite, Great Falls of the Potomac River, Maryland	..	0.35
Soft brick	2.211	16.46
Hard brick	2.294	1.07
Marble, coarse dolomite, Mount Pleasant, New York	2.860	0.91

The specimens operated upon, it should be stated, were cut in the form of inch cubes. Each was immersed for half an hour in the boiling solution of sulphate of soda, and then hung up to dry, this performance being repeated daily throughout the four weeks which the experiment lasted.

Although as above noted this process is practically abandoned, the series of tests given was productive of certain results which are well worth a moment's consideration. Thus the red sandstone from Seneca Creek, Maryland, with a specific gravity of 2.672, or a weight per cubic foot of 167 pounds, lost by disintegration but 0.70 grains. This

was the stone ultimately selected for the Smithsonian Institution building, and the structure as a whole is to-day probably in as good a state of preservation as any of its age in the United States. The second stone, from Acquia Creek, Virginia, with a specific gravity of 2.23, or a weight per cubic foot of but 139.37 pounds, and which lost 18.6 grains is the one in the construction of the White House and the old portions of the Capitol, Interior Department and Treasury buildings. This stone has proven so poor and disintegrates so badly that the buildings are kept in a condition anywise presentable only by repeated applications of paint and putty. The results obtained with hard and soft brick are also very striking; the one weighing at the rate of 138 pounds per cubic foot, losing 16.46 grains, while the harder brick, weighing at the rate of 143 pounds, lost but 1.07 grains. If anything can be learned from the series it is that with substances having the same composition, those which are the most dense—which are the heaviest bulk for bulk—will prove the more durable. The results obtained on coarse and fine varieties of Portland sandstone suggest at least that water would freeze out of the coarser stone, and therefore create less havoc than in that of finer grain, a probability to which I have already referred.[1]

More recently this method has been reinvestigated by Dr. L. McI. Luquer[2] with a view of ascertaining what relation may exist between the sulphate of soda and the freezing methods when both are carried on under the same conditions. In these tests recognition is taken of the fact brought out a generation or more ago to the effect that a hot solution of a sulphate of soda is likely to undergo decomposition and give rise to free alkali (Na_2O) which exerts a powerful chemical effect and weakens the cohesive power of the granules. The method employed, as given in the paper above referred to, was as follows:

The specimens, which had been carefully prepared, brushed, dried and weighed, were boiled in the sulphate of soda for half an hour, in order to get complete saturation. At the end of the half hour it was noticed in every case that the solution was slightly alkaline, although at the start it had been neutral. In order to prevent any continued

[1] Stones for Building and Decoration, 2d ed., p. 438.
[2] Trans. Am. Soc. Civil Engineers, Mar. 1895, p. 235.

chemical action the beakers were emptied, the specimens rapidly washed with water, and the beakers immediately refilled with the neutral sulphate solution. After soaking for several hours the specimens were hung up by threads, and left for 12 hours (during the night) in a dark room.

In the morning all the specimens were covered with an efflorescence of the white sulphate of soda crystals; they were then allowed to soak in the solution during the day and again hung up at night. Efflorescing for about 12 hours and soaking for about the same time constituted a period. The experiments lasted for eight periods, and were conducted in this way in order to make them correspond with those made with freezing water, as in the cold-storage room the specimens could only be changed night and morning.

In two cases the specimens were allowed to effloresce for 36 instead of 12 hours, to insure thorough action of the salt. The experiments thus really lasted for 10 days. It was deemed that eight periods or days were sufficient, as de Thury states that if a specimen is acted on by this method of testing, the effect will be noticed in five days. The general opinion of others seems to be also, that a week or eight days is long enough to obtain good results. During the test the solution was renewed from time to time, and appeared to remain neutral. The temperature of the room varied from 60° to 70° Fahr. (18° to 21° Cent.). Those specimens most affected began to show the disintegrating action of the solution very early in the course of the experiments. At the end of the 10 days the specimens were sprayed with the stream from a wash bottle to remove any adhering particles, washed in water to remove the sulphate of soda, carefully dried in an air bath at about 120° Cent., and weighed again.

The difference between the weights was taken as the loss due to the action of the sulphate of soda. The results are given in tabular form below.

In the experiments of Prof. Dodge[1] carefully prepared cubes the dry weight of which had been previously ascertained were placed in a shallow iron pan, nearly covered with water and exposed to the open air, but in a sheltered place, to freezing and thawing, for a period

[1] Geol. and Nat. Hist. Survey of Minnesota. Final Reports, vol. i, p. 186.

of 8 weeks during February and March. To thaw, the specimens were occasionally brought into a warm room for a few hours. After the exposures, the pieces were carefully examined, then dried for six days and weighed, the difference between the first and second weight indicating the loss of material by the frost action. In the freezing experiments by Dr. Luquer, above referred to, the specimens were allowed to thaw and soak in water during the day, and were hung up and frozen at night. The experiments lasted the same number of periods as did the sulphate tests. The temperature of the cold room in which the freezing was carried on varied from 4° to 10° Fahr. and that of the room in which the soaking and thawing was done, 85° Fahr. After the freezing the specimens were allowed to soak in water for the same period as did those used in the sulphate of soda experiments, after which they were dried and weighed. During the progress of the experiments, it is stated the deterioration was so slight that the effect was scarcely noticeable, the sandstones only showing the effect of a slight residue in the bottom of the pails in which the experiments were performed. Below are given in tabular form the results obtained by both processes. It will be noted the action of the sulphate was by far the most energetic, but it cannot be learned that there is any definite relationship. Hence all things considered it seems best that the sulphate method be abandoned, and the actual freezing test always resorted to.

Results of Experiments with Sulphate of Soda.

No.	Specimens tested.	Original weight in grams.	Loss of weight in grams.	Loss of weight in parts in 10,000.
1	Coarse crystalline dolomitic marble	71.9020	0.0775	10.78
2	Medium crystalline dolomitic marble	93.8861	0.1597	17.01
3	Fine-grained limestone	67.0964	0.1744	25.99
4	Coarse-grained red granite	71.8648	0.1115	15.51
5	Medium-grained red granite	56.4939	0.0370	6.55
6	Fine-grained gray granite	43.5910	0.0225	5.16
7	Rather fine-grained gneiss	61.8687	0.0392	6.33
8	Norite, "Au Sable" granite	35.1173	0.0135	3.84
9	Decomposed sandstone	39.4294	1.9010	482.12
10	Very fine-grained sandstone	37.7760	0.1800	47.65
11	Sandstone	28.0325	0.4070	145.18
12	Pressed brick	37.4025	0.0930	24.86
51	Decomposed sandstone	22.9660	3.7235	1 621.31
52	Sandstone	23.9001	0.1381	57.78

Results of Experiments with Frost.

No.	Specimens tested.	Original weight in grams.	Loss of weight in grams.	Loss in weight in parts in 10,000.
1	Coarse crystalline dolomitic marble......	63.6407	0.0197	3.10
2	Medium crystalline dolomitic marble....	93.9851	0.0216	2.30
3	Fine-grained limestone.................	55.2787	0.0115	2.07
4	Coarse-grained granite..................	52.2787	0.0072	1.38
5	Medium-grained red granite.............	63.4693	0.0112	1.76
6	Fined-grained gray granite..............	58.6149	Very slight, about same as No. 5.	
7	Rather fine-grained gneiss..............	52.7260	Very slight, about same as No. 5.	
8	Norite, "Au Sable" granite............	44.4665	Very slight, less than No. 5.	
9	Decomposed sandstone..................	38.4055	0.2640	68.74
10	Very fine-grained sandstone.............	39.5120	0.0420	10.63
11	Sandstone..............................	21.9437	0.0312	14.21
12	Pressed brick..........................	37.1790	0.0255	6.86
51	Decomposed sandstone....	24.1020	0.0610	25.31
52	Sandstone	20.2285	0.0180	8.89

(6) Tests to ascertain ratio of expansion and contraction. Tests of this nature are of value for the purpose of (1st) making proper allowance for expansion in parapet walls, and similar situations, and (2nd) because through expansion the tenacity of the stone is weakened. As long ago as 1832 Col. Totten, in view of the difficulty of making permanently tight joints even with the strongest cements, instituted a series of experiments to ascertain the actual expansion and contraction of granite, sandstone and marble when subjected to ordinary temperature. He found the rate per inch for each degree of temperature for granite to be .000004825 inch; for marble .000005668 inch, and for sandstone .000009532 inch. That is to say a block of stone one foot in length raised from a temperature of freezing (32°) to that of a hot summer day, say 90°, would be expanded to the amount of .005416 inch or would be 1.005416 inches in length. The amount is apparently trifling yet it produces a weakening effect which is of both economic and geologic significance.

Within recent years some good work in this line has been done under the direction of the Ordnance Department of the U. S. Army.

The method of testing has consisted in placing carefully measured bars of stone in baths of cold water (32° F.), hot water (212° F.), and back to cold water once more. It was noted that in none of the samples tested did the stone quite regain its first dimensions on cooling but showed a slight "permanent swelling." Since this can only mean that the particles composing the stone have separated though ever so slightly, it is an important matter as it necessitates a weakening which is shown by actual pressure tests. The tables given below show the amount of permanent swelling occurring in stone bars of a gauged length of 20 inches.[1]

Granites.

Description.	Amount of permanent swelling. Inch.
From Braddock quarries near Little Rock, Ark. (Light)	.0048
From Braddock quarries near Little Rock, Ark. (Dark)	.0024
From Millbridge, Maine, White Rock Mountain	.0032
From Broad Rock quarry, Chesterfield County, Virginia	.0047
From Korah Station, Virginia	.0048
From Exeter, Tulare County, California	.0019
From Rockville, Stearns County, Minnesota	.0061
From Sioux Falls, Minnesota	.0059
From Troy, New Hampshire	.0021
From Branford, Connecticut	.0043
	.0033
From Milford, Massachusetts	.0071
Mean	.0040

Marbles.

Description.	Amount of permanent swelling. Inch.
Rutland, white, Vermont	.0135
Rutland, white, Vermont (second exposure)	.0029
Mountain Dark, Vermont	.0064
Sutherland Falls, Vermont	.0107
From St. Joe, Searcy County, Arkansas	.0196
From De Kalb, St. Lawrence County, New York	.0055
From Marble Hill, Georgia	.0077
Mean	.0090

[1] Rep. on Tests of Metals, etc., at Watertown Arsenal, U. S. War Dept., 1895, p. 322-23.

Limestones.

Description.	Amount of permanent swelling. Inch.
From Isle La Motte, Vermont	.0081
From Wasioja, Minnesota	.0024
From Fort Riley, Kansas	.0052
From Beaver, Carroll County, Arkansas	.0060
From Mount Vernon, Kentucky	.0075
From Darlington quarry, Rockwood, Illinois	.0114
From Bowling Green, Kentucky	.0077
	.0119
From Bedford, Washington County, Indiana	.0025
Mean	.0070

Sandstones.

Description.	Amount of permanent swelling. Inch.
From Cromwell, Connecticut	.0067
From Worcester quarry, East Longmeadow, Massachusetts	.0022
From Kibbe quarry, East Longmeadow, Massachusetts	.0029
	.0003
From Maynard quarry, East Longmeadow, Massachusetts	.0019
From Kettle River quarry, Pine County, Minnesota	.0018
From Cabin Creek quarry, Johnson County, Arkansas	.0018
From Sebastian County, Arkansas	.0015
From Bourbon County, Kansas, "Bandera stone"	.0017
From Piedmont quarry, Alameda County, California	.0174
From Olympia, Washington	.0035
From Chuckanut, Washington	.0052
	.0148
From Tenino, Thurston County, Washington	.0035
Mean	.0047

(7) Tests to ascertain the fireproof qualities of stone. The expansive power of natural temperatures is but slight in comparison with that induced by the heat of a burning building, which is at times so great that no natural material can be expected to remain uninjured. Several years ago H. A. Cutting[1] made a small series of experiments to ascertain the relative powers of resistance of various stones to artificial temperatures. According to his results the heat resisting capacity of the various stones tested stands in the following order, the

[1] Weekly Underwriter.

first mentioned being the least affected: (1) marble, (2) limestone, (3) sandstone, (4) granite, and (5) conglomerate. The tests were however scarcely sufficient to fully establish any such law. Prof. Dodge, to whose work on the Minnesota Survey reference has already been made, proceeded as follows:

The prepared samples were first heated to a red heat in a muffle furnace, the temperature being raised gradually. Twice each sample was removed with tongs, and carefully inspected to note the effect of heating.

After this heating test the samples, while still very hot but at a temperature below redness, were immersed in a tank of water for a few minutes. The action of the water in causing cracking or crumbling was noted. Such tests are really too severe to be used in any but the most extreme cases since no stone can be expected to pass through such an ordeal unharmed.

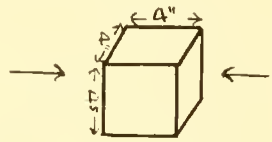


FIG. 15.—Cube for crushing tests.

(8) Tests to ascertain resistance to crushing. This is far the most common test that is applied to stone. Concerning the utility of such tests as usually applied, the writer has expressed himself elsewhere.

The first systematic and really exhaustive series of these tests made in America were those of Q. A. Gillmore, of the Engineer Department, United States Army, whose results were published in the Annual Report of the Chief of Engineers for 1875.

The size of specimens operated upon by Gillmore in the systematic part of his work was that of a two inch cube. During his preliminary experiments he found that at least within certain limits the compressive resistance of cubes, per square inch of surface under pressure increases in the ratio of the cubic roots of the sides of the respective cubes expressed in inches. Thus the actual resistance of a ½ inch cube, expressed per square inch, was about 6,080 pounds, while that of a 4 inch cube, that is one having 8 times the length of side, was

11,720 pounds per square inch. The general conclusions arrived at was that having ascertained from an average of several careful trials the crushing resistance of a 1 inch cube, an 8 inch cube of the same nature should show twice as much resistance per square inch of crushing surface as the 1 inch. This conclusion was not fully borne out by later experiments but enough was gained to show that for purposes of fair comparison it was necessary that all tests be made on cubes of approximately the same size. Gillmore's tests showed also that much depends on the breadth when compared with the height of the specimens tested. Thus he found that while an inch cube of Berea standstone crushed under a weight of 9500 pounds, a block of the same stone 1 inch thick by two inches square, and which contained therefore only four times the amount of material sustained not merely 4 x 9500 or 38,000 pounds but 76,000 pounds. When the height or thickness of the specimen was doubled, so as to have the form of a two inch cube it sustained but 50,000 pounds, and when the height was increased to twice that of the width, or base, it sustained only 44,000 pounds.

Gillmore further found that there was a great difference in the results obtained by crushing between plates of various kinds of material as wood, leather, lead and steel, in every case the tests between steel plates yielding the highest results, a fact which was shown to be due to the lateral spreading action of the other substances mentioned. As a result of these and other trials which need not be given in detail here it seems best that pressure tests be made on two inch cubes, the faces of which have been carefully sawn or ground so that no incipient fractures are developed, and those which are to come in contact with the steel plates rubbed with a very thin coating of plaster of Paris to fill in all inequalities. In the process of testing it is customary to note (1st) the number of pounds registered by the crushing machine when the stone first begins to show signs of fracture, and (2nd) the number registered when it actually crushes. Both of these phenomena are noted in the accompanying tables (p. 145, 156, 164).

The result of many experiments has been to show that most laminated or bedded rocks will bear a greater pressure in a direction at

right angles to their bedding than parallel thereto. That is, a block will stand more if laid on its natural bed than if stood on edge. This result may not always appear in a small series of tests owing to sundry imperceptible differences in the specimens tested, but it is nevertheless true in a general way.

Study of the results of large numbers of tests that have been made at periods extending over many years have shown that the results of recent tests are much higher than those several years ago, even on the same class of material. This result, which is simply due to the perfection to which the methods have been brought, is so great that very unfair deductions may be drawn regarding the relative strength of materials tested at different times under perhaps different conditions. In fact there are few things more misleading than a tabulated statement of crushing strengths, made at intervals covering many years, on cubes of varying sizes, and under conditions which are not stated.

It is interesting to note the form assumed by the fragments as a result of crushing.

As a rule, a perfectly homogeneous rock gives rise to conical or pyramidal fragments according as the stone is friable, of a pronounced granular structure like sandstone, or compact as are most granites. Stones crushed on edge naturally split up into flakes or slabs. In the plate herewith given (Plate VI) are shown the shape of the fragments formed during the tests tabulated. (See p. 113.)

In all this work of testing the strength of stone it is well to remember that stones as a rule are apparently weaker when saturated with moisture than when dry. It is true that we have not at hand to-day sufficient data for proving this conclusively, but such data as are at hand are more than merely suggestive. Thus MM. Tournaire and Michelot have shown [1] that cubes of chalk three decimeters in diameter crushed wet under a pressure of but 18.6 kilograms; but when air dried under 23.5 kilograms and when stove dried under 86.2 kilograms. Delesse's experiments on 5 centimeter cubes of chalk and the "calcaire grossier" found that the chalk when wet crushed under a pressure of 12.9 kilograms; when air dried 23.6 kilograms, and when

[1]American Journal of Science, 3rd series, vol. xvi, 1878, p. 151.

stove dried 36.4 kilograms. The limestone (calcaire grossier) crushed when wet under 24.35 kilograms, when air dried kilograms, and when stove dried under 42.7 kilograms. Inasmuch as stones in a foundation are subject to periodic or perhaps constant saturation these facts are worthy of consideration.

It is well to note here too that the effect of temperature changes upon stone is weakening. In the tests made by the Army Engineers to which we have already referred[1] it was found that samples which had been submitted to the hot and cold water tests to ascertain their coefficient of expansion and contraction had suffered to a remarkable degree. The average result showed that the stones from the water baths lost in strength on an average 34.9 per cent, the granites, after passing through both hot and cold water tests, possessing but 83.7 per cent their original strength; the marbles 46.2 per cent; the limestones 58.8 per cent, and the sandstones 66.9 per cent.

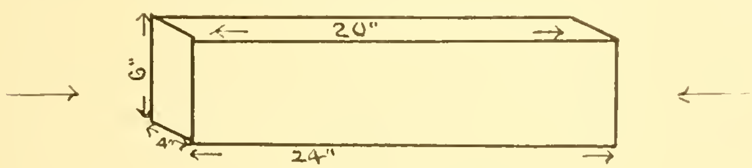


FIG. 16.—Bar for expansion tests.

Tests on bricks made by the United States Army Engineers showed that the wet samples had as a rule but 85 per cent the strength of the dry ones, the greatest loss in strength occurring in medium hard and hard brick.

(9) Tests to ascertain elasticity of stone. Tests to ascertain the elasticity of stone when subjected to compressive and transverse strains, have also been made by the United States Army Engineers, and the results obtained may well be noted briefly here, though for details the reader is referred to the original publications.[2]

The tests of elastic properties under compression were made upon prisms 4-in. by 6-in. by 24-in., the loads being applied parallel to the

[1] Report on Tests of Metals, etc., 1895.

[2] Report of the Tests of Metals, etc., made at Watertown Arsenal. Years 1890, 1894 and 1895. Washington, D. C.

direction of the long sides (see Fig. 16), the compressibility being measured by means of a micrometer. It was found here, as in the tests for ascertaining expansion that the stones shortly developed a permanent "set," from which they did not recover during the period of time over which the observations were extended.

COMPRESSIVE ELASTIC TESTS.

	APPLIED LOADS.		20″ IN GAUGED LENGTHS.	
	Total pounds.	Per square inch pounds.	Compression inch.	Set inch.
Granite, Milford, Mass	215,460	9,000	0.0229	.0015
Granite, Troy, New Hampshire	243,600	10,000	.0411	..
Granite, Troy, New Hampshire	219,240	9,000	.0379	.0062
Marble, Cherokee, Georgia	144,960	6,000	.0133	..
Marble, Cherokee, Georgia	48,320	2,000	.0037	.0006
Limestone, Mount Vernon, Kentucky	59,832	2,400	.0182	..
Limestone, Mount Vernon, Kentucky	2,493	100	..	.0032
Sandstone, East Long Meadow, Mass	96,400	4,000	.0554	..
Sandstone, East Long Meadow, Mass	2,410	100	..	.0136

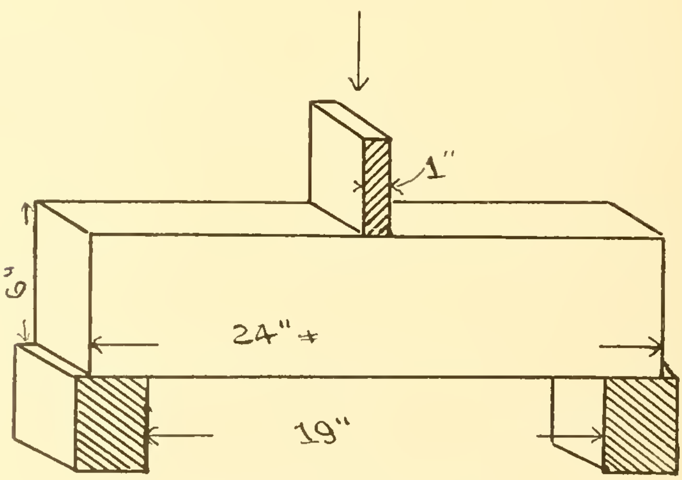


FIG. 17.—Bar for elasticity tests.

The transverse tests were made on similarly prepared prisms, supported at the ends, the load being applied at the middle as shown in Fig. 17. In the table below is given the results of a few selected tests, as determined by the authorities referred to, the term modulus of rupture signifying the weight in pounds under which the bar breaks; only the maximum results are tabulated.

TRANSVERSE TESTS.

Pink Granite from Milford Pink Granite Company, Boston, Mass.

No. of tests.	Distance between end supports.	Dimensions. Breadth.	Dimensions. Depth.	Ultimate strength. Total.	Ultimate strength. Modulus of rupture.
	Inches.	Inches.	Inches.	Pounds.	Pounds.
203	19	4.03	6.03	9,020	1,745

Granite from Pigeon Hill Granite Company, Rockport, Mass.

No. of tests.	Distance between end supports.	Dimensions. Breadth.	Dimensions. Depth.	Ultimate strength. Total.	Ultimate strength. Modulus of rupture, R.
	Inches.	Inches.	Inches.	Pounds.	Pounds.
204	19	4.03	6.02	12,320	2,404
205	19	4.01	6.06	12,450	2,416

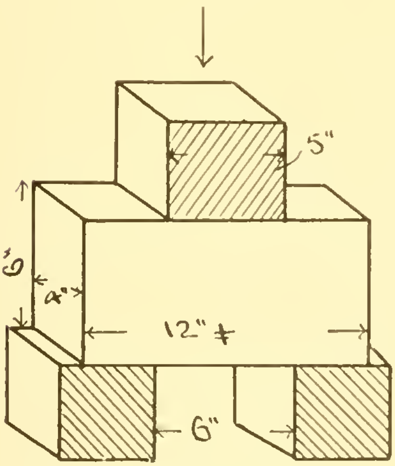


FIG. 18.—Bar for shearing tests.

(10) Tests to ascertain resistance to shearing. The term shearing as used in geology includes a strain due not merely to pressure in one direction, but also those due to pulling or thrusting in all directions up to those perpendicular to the first. It is a form of strain likely to be brought to bear on stone in many parts of a building, bridges, etc., and is by no means unimportant. As performed by the Army Engineers the test consists in subjecting prepared prisms supported at each end by blocks 6 inches apart, to pressure applied by means of a "plunger" having a face 5 inches wide, there being then a clearance space of half an inch between the sides of the plunger and the blocks on each side, below (see Fig. 18).

The results of a few experiments of this nature are given below. It is worthy of note that "before the shearing strength was reached during the tests, tension fractures were developed on the under side of the stone midway the 6-inch free span, and there were instances in which longitudinal fractures opened in the ends of the stones, corresponding to shearing along the grain in the tests of timber."

NATURAL STONES.—SHEARING TESTS.

Stones from Charles River Stone Company, Boston, Mass.

No. of tests.	Description.	Shearing dimension.	Shearing area.	Transverse fracture developed on tension side.	Shearing strength. Total.	Shearing strength. Per square inch.	Surfaces sheared.
		Inches.	sq. in.	lbs.	lbs.	lbs.	
240	Milford granite, Milford, Mass........	4.02 × 6.03 × 2	48.48	24,800	108,400	2,236	one
241	" " " "	4.02 × 6.01 × 2	48.32	27,300	138,800	2,872	two
242	Branford granite, Branford, Conn.....	4.04 × 6.01 × 2	48.56	18,900	93,500	1,925	one
243	" " " "	4.03 × 6.01 × 2	48.44	19,600	84,400	1,742	one
244	Troy granite, Troy, New Hampshire...	4.03 × 6.00 × 2	48.36	29,900	107,900	2,231	one
245	" " " " " ...	4.06 × 6.02 × 2	48.88	34,400	107,400	2,197	one
246	Maynard stone, E. Long Meadow, Mass.	3.99 × 6.01 × 2	47.96	25,800	53,700	1,120	one
247	" " " " "	4.02 × 6.00 × 2	48.24	19,900	62,100	1,287	two
248	Worcester stone, E. Long Meadow, "	4.00 × 6.00 × 2	48.00	22,900	66,400	1,383	two
249	" " " " "	4.00 × 5.98 × 2	47.84	26,200	52,700	1,102	two
250	Kibbe stone, East Long Meadow, Mass.	4.00 × 6.00 × 2	48.00	25,100	47,600	992	two
251	" " " " "	4.00 × 6.00 × 2	48.00	29,400	62,800	1,308	one
252	Southern marble, Marble Hill, Georgia.	4.02 × 6.00 × 2	48.24	26,700	56,100	1,163	one
253	" " " " "	4.02 × 6.00 × 2	48.24	30,300	72,400	1,501	one
254	Tuckahoe marble, Tuckahoe, New York.	4.02 × 6.01 × 2	48.32	29,850	75,100	1,554	one
255	" " " " "	4.02 × 6.00 × 2	48.24	35,700	68,800	1,426	one

NATURAL STONES.—SHEARING TESTS.

Pink Granite from Milford Pink Granite Company, Boston, Mass.

No. of test.	Shearing dimensions.	Shearing area.	Transverse fracture developed on tension side.	Shearing strength Total.	Shearing strength Per square inch.	Surfaces sheared.
	Inches.	sq. inch.	Pounds.	Pounds.	Pounds.	
262	6.01 × 4.02 × 2	48.32	38,300	88,200	1,825	one

Granite from Pigeon Hill Granite Company, Rockport, Mass.

No. of test.	Shearing dimensions.	Shearing area.	Transverse fracture developed on tension side.	Shearing strength. Total.	Shearing strength. Per square inch.	Surfaces sheared.
	Inches.	sq. inch.	Pounds.	Pounds.	Pounds.	
263	6.05 × 4.00 × 2	48.40	45,400	99,100	2,047	..
264	6.01 × 4.00 × 2	48.08	38,600	50,600	1,052	..

(11) Tests to ascertain the specific gravity. The determination of the specific gravity of a stone, or its weight when compared with an equal volume of water, is of interest, and sometimes of practical importance. Of two stones of the same mineral nature, the one having the highest specific gravity, that is the greatest weight bulk for bulk, will be the least absorptive, and hence as a rule the most durable. Moreover the specific gravity determination affords an easy method of determining the weight of any stone per cubic foot. The weight of a cubic foot of distilled water, at a temperature of 4° C., is 62.5 pounds. Hence, if we find that a stone has a specific gravity of 2.65, that is to say is 2.65 times as heavy as water, we get its weight by simply multiplying 62.5 by 2.65 which gives us 165.62, which is the average weight per cubic foot of granite. Specific gravity tests are made by carefully weighing a small piece of the rock in the air, and then weighing it again in water, the weight in the last case of course being less. The figures representing the weight in air divided by those representing the loss of weight in water, give the specific gravity. It is customary in making the weighings to have the rock fragment suspended to the arm of the balance by a fine wire, or hair, so as permit of its being readily immersed in water for the second weighing. In very accurate determinations the vessel of water containing the fragment should be placed upon the bell jar of an air pump and the air exhausted in order to remove the air from and admit the water to the pores of the stone.

The Testing of Roofing Slates.

The condition of exposure under which slates on a roof are placed are such as to require a slight modification of the tests as above outlined.

Obviously the matters of toughness and permanency of color are

of greatest importance. The first is readily ascertained by direct tests made on the fresh slates, and on samples which have been submitted to the corrosive action of acids. The matter of permanence of color is not however so easily solved, and indeed as yet the cause of the fading of some of our slates is not well understood.

The best series of tests that, so far as the writer is aware, have yet been inaugurated, are those of Prof. Mansfield Merriman,[1] from whose paper the facts given below are mainly derived. The tests here quoted were made wholly on Pennsylvania materials. Others made on Peach Bottom materials are quoted on pp. 228-231.

The strength and toughness of slate, writes Prof. Merriman, are important elements in preventing breakage in transportation and handling, as well as in resisting the effect of hail, or of stone maliciously thrown upon the roof. They are also brought effectively into play by the powerful stresses produced by the freezing of water around and under the edges. Porosity is not a desirable property, for the more water absorbed the greater the amount of disintegration through freezing. Density tests are of value, since the greater the specific gravity of one of several similar substances, the greater is its strength. Hardness may or may not be a desirable quality, accordingly as it is related to density or to brittleness. Lastly a test for corrodibility, or the capacity of being disintegrated by the chemical action of smoke and of fumes from manufactories, is desirable.

(1) Strength and Toughness.—The tests were made upon selected pieces 12 inches wide, 24 inches long and varying from $\frac{3}{16}$ to $\frac{1}{4}$ of an inch in thickness. The pieces were supported in a horizontal position, upon wooden knife edges 22 inches apart and the loads were applied upon another knife edge placed half way between the supports. This load being applied by means of sand running out of an orifice in a box, at the rate of 70 pounds per minute, the flow being checked by means of an electric attachment the moment rupture took place. The deflection or bending of the slate in the pieces tested was sufficiently great to permit of easy measurement, and both the amount of bending —indicating toughness—and the actual strength of the slate could

[1] Trans. Am. Soc. of Civil Engineers, vol. xxvii, 1892, pp. 331-349.

be thus ascertained by a single test. The test of specific gravity of slate and the porosity are made in the same way as with other stone.

(2) CORROSION BY ACIDS.—In making these tests very dilute solutions were prepared, consisting of 98 parts water, 1 part of hydrochloric acid and one part of sulphuric acid. In this solution pieces of slate some 3 x 4 inches in size were immersed for 63 hours each, after careful weighing. At the expiration of this time they were removed, allowed to dry for two hours, and again weighed, the differences between the first and second weighing of course representing the amount of corrosion.

(3) SOFTNESS OR CAPACITY TO RESIST ABRASION.—This was determined by simply holding a weighed block of slate some 4 x 4 inches against a grindstone under a constant pressure of 10 pounds. The table below is given to show the mean results of the tests above enumerated, on certain Pennsylvania slates, as made by the authority quoted. The general conclusions adopted as a result of these tests are also given.

MEAN RESULTS OF PHYSICAL TESTS.

Property.	Measured by	Albion slates.	Old Bangor slates.	Mean of both.
Strength	Modulus of rupture, in pounds per square inch	7,150	9,810	8,480
Toughness	Ultimate deflection, in inches, on supports 22 inches apart	0.270	0.313	0.291
Density	Specific gravity	2.775	2.780	2.777
Softness	Weight in grains, abraded on grindstone under the stated conditions	80	128	104
Porosity	Per cent of water absorbed in 24 hours, when thoroughly dried	0.238	0.145	0.191
Corrodibility	Per cent of weight lost in acid solution in 63 hours	0.547	0.446	0.496

CONCLUSIONS.—The above investigation seems to indicate the following conclusions regarding the soft roofing slates of Northampton county, Pennsylvania:

1. Slates containing soft ribbons are by common consent of an inferior quality, and should not be used in good work.

2. The soft roofing slates weigh about 173 pounds per cubic foot,

and the best qualities have a modulus of rupture of from 7000 to 10,000 pounds per square inch.

3. The stronger the slate, the greater is its toughness and softness, and the less is its porosity and corrodibility.

4. Softness, or liability to abrasion, does not indicate inferior roofing slate; but, on the contrary, it is an indication of strength and good weathering qualities.

5. The strongest slate stands highest in weathering qualities, so that a flexural test affords an excellent idea of all its properties, particularly if the ultimate deflection and the manner of rupture be noted.

6. The strongest and best slate has the highest percentage of silicates of iron and aluminum, but is not necessarily the lowest in carbonates of lime and magnesia.

7. Chemical analyses give only imperfect conclusions regarding the weathering qualities of slate, and they do not satisfactorily explain the physical properties.

8. Architects and engineers who write specifications for roofing slate will probably obtain a more satisfactory quality if they insert requirements for a flexural test to be made on several specimens picked at random out of each lot.

9. Although the field of this investigation is probably not sufficiently extended to fully warrant the recommendation, it is suggested that such specifications should require roofing slates to have a modulus of rupture, as determined by the flexural test, greater than 7000 pounds per square inch.

Probably more can be learned regarding the lasting powers of a slate by microscopic methods than in any other class of rocks. As the writer has elsewhere noted,[1] the roofing slates occupy a very interesting position in the lithologic series. Originally formed as a fine silt on a sea bottom, they owe their fissile properties not to sedimentation but to squeezing and shearing forces such as are incidental to the formation of mountain chains. But this shearing, while developing schistosity, or cleavage, has also brought about other structural modifications in the slate which, although not so manifest,

[1] Trans. Am. Soc. of Civil Engineers, vol. xxxii, 1894, p. 540.

are nevertheless of great importance. If we examine a thin section of a slate under the microscope we shall find that the individual particles of quartz and feldspar, etc., of which they are composed, are all arranged with their longer axes parallel with each other and with the direction of cleavage. In fact it is to this cause that the finely fissile nature of the slate is largely due. But this is not all. Pressure always causes heat, and since all rocks lying in the ground contain more or less moisture, the rock becomes permeated with warm or hot solutions which may be productive of partial solution and recrystallization. In fact, our roofing slates pass by insensible gradations into crystalline schists. So far as the writer's experience goes, the greater the amount of crystallization, that is the more nearly the slates approach the crystalline schists in structure and composition, the tougher and more durable they are likely to be. It is unfortunate that this crystallization interferes to some extent with the fissile property, the slates of this nature yielding thicker slabs, and with less even surfaces. Such, while more desirable, demand increased strength in roofing timbers. The point to be made here is, however, that the microscope, in showing the crystalline condition of the slate, the presence or absence of pyrite, or of free carbonates of lime, iron or magnesia, such as are likely to be corroded by rains, will enable one to draw some inference regarding its lasting power. A chemical analysis shows what the slate contains, but it does not show the form of combination of the various elements.

AN ACCOUNT OF
THE CHARACTER AND DISTRIBUTION OF MARYLAND BUILDING STONES

TOGETHER WITH

A HISTORY OF THE QUARRYING INDUSTRY

BY

EDWARD B. MATHEWS.

INTRODUCTION.

The rocks of the state of Maryland present many varieties of excellent building and decorative stones. The greater amount of the product is obtained from that portion of the state north of Washington and east of Harpers Ferry, W. Va., which has been termed the Piedmont Plateau, and which includes some of the oldest rocks found in the state. The central location of this area, traversed by two main railroad lines and several more local ones, places it within convenient distance of the prominent cities and towns of the Middle Atlantic coast and renders the products both valuable and available wherever the local conditions are otherwise favorable. Counteracting the value of this central location, however, is the fact that the state of Maryland represents but a section across a series of geological formations, which are present in Pennsylvania and Virginia, where there are offered similar opportunities for quarrying building stone. In some instances operations were commenced in these areas earlier than in Maryland, with the result that trade has been diverted to neighboring states, which might be gained for Maryland by more energetic and intelligent action on the part of the local operators. At the present time the operations in the area are in no wise commensurate with the supply of material at hand, and the demand which might be devel-

oped if sufficient forethought and care were expended to make the output uniformly and economically quarried.

The rich variety in the rocks adapted to structural and decorative purposes renders a description of each variety out of the question, and it becomes necessary to treat the occurrences under the following heads: I. The Granites and Gneisses. II. The Marbles, Serpentines and Limestones. III. The Quartzites and Sandstones. IV. The Slates and Flags.

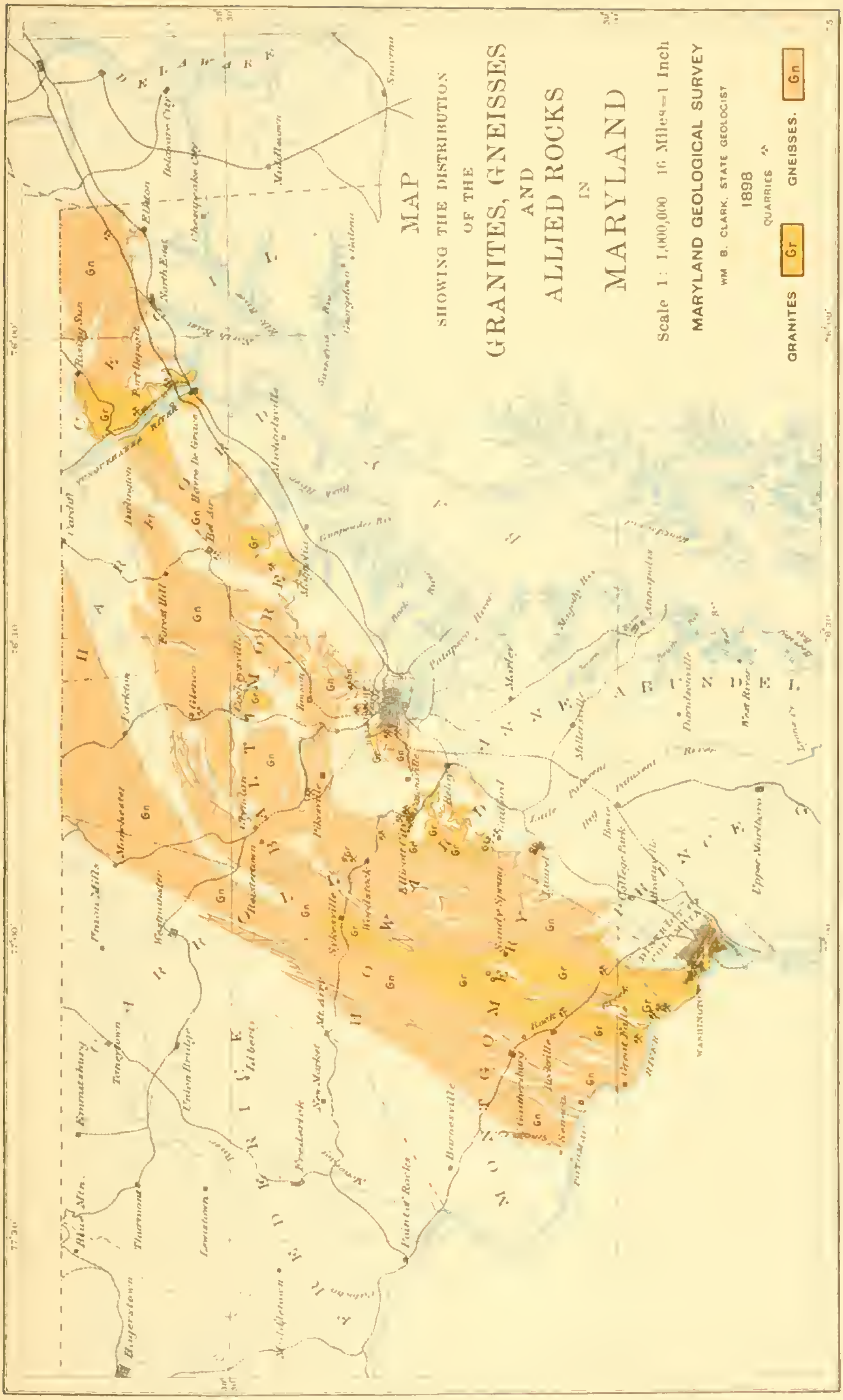
Previous Publications.

The bibliography at the end of this chapter is the somewhat dry expression of the amount of study which has been carried on regarding the building stone products of the state, their geological occurrence, properties and industries. From the books and papers therein enumerated one may glean the following resumé of the results which have been accomplished.

The earliest reference of scientific value to the quarrying of Maryland stone is found in a paper by H. H. Hayden (1), published in 1811. In this very rare and interesting report we learn, that, at the time of writing, the stone "a mile and a half from Baltimore" (location of the present quarries on Jones' Falls) was regarded as "highly valuable and useful in various branches of masonry," and that it was "quarried on both sides of Jones' Falls, to considerable advantage to the proprietors."

Eight years later the Rev. Elias Cornelius (2), after an extended trip through the southern states from Boston to New Orleans and return, gave a summary of his observations on the mineralogy and the geology of the country traversed to Professor Silliman, who published the same in the first volume of his journal. This letter gives the earliest account of the "Potomac Marble" which has been found in any scientific journal, and furnishes information concerning the cost of the original columns in the old Hall of the House of Representatives in Washington, as well as the name of the man who first brought this peculiar rock into use.

The next reference to the quarries of Maryland is found in a paper by Mr. William E. A. Aikin (3), who was at that time Professor of


MAP
SHOWING THE DISTRIBUTION
OF THE
GRANITES, GNEISSES
AND
ALLIED ROCKS
IN
MARYLAND
Scale 1 : 1,000,000 16 Miles = 1 Inch
MARYLAND GEOLOGICAL SURVEY
WM. B. CLARK, STATE GEOLOGIST
1898
QUARRIES
GRANITES Gr
GNEISSES Gn

Natural Philosophy and Chemistry in the Mount Saint Mary's College in Emmitsburg. In this paper reference is made to the fact that "the granite may be well seen in the neighborhood of Ellicott's Mills, where there are extensive quarries that furnish vast quantities for the Baltimore market," and the fact is noted that "at one place [Ijamsville?] quarries have been opened and furnish a tolerable, coarse roofing slate."

Mention is also made of the quarries in the "Potomac marble" and of many others about Frederick and Hagerstown while the author notes that "a few miles east of Hagerstown, the exact spot I am not acquainted with, this stratum [Shenandoah limestone] includes a bed of white and perfectly fine grained limestone, which is quarried for white marble, and answers well for that purpose."

In Ducatel and Alexander's "Report on the projected survey of Maryland," published in 1834 (4), there is a summary of the existing industries dependent on the natural resources, and a plea for greater information concerning them. In this summary there are brief and incidental references to the granites of Port Deposit and Ellicott City; to the Seneca and Sugarloaf sandstones; to the slates of central Maryland; and to the marbles of Point of Rocks, Carroll county and Boonsborough. The total amount of information, however, would scarcely fill a page, and the references are of little more than historical value. From the date of this earliest report until 1836 the Geologist and Engineer were so busy with the survey and study of the features of eastern and southern Maryland that no reference is made to the structural materials of the northern tier of counties before the publication of the "Report on the New Map of Maryland," in 1836 (5). In this paper attention is called to the sedimentary origin of the Baltimore gneiss, the peculiar weathering of the granites at Woodstock, and the probable source of the pebbles in the "Capitol or Potomac breccia." Succeeding reports of Ducatel and Alexander give a few more details in the discussion of the resources of the different counties, which may be found as follows: Cecil and Montgomery in the report for 1837 (6); Harford and Baltimore in that for 1838 (7); Frederick and Carroll in that for 1839 (8); and western Mary-

land in the last for 1840 (9). The most important work on the building stones of the state published prior to the war is found in a Report of the Board of Regents of the Smithsonian, presented to the Senate in 1849. This contains, besides many letters showing the price of stone and the state of the industry at that time, the following reports: One by Dr. Charles G. Page (10) "To the Building Committee of the Smithsonian Institution on the action of frost upon certain materials for building"; another by Mr. James Renwick, Jr. (11), entitled "Report to the Building Committee of the Smithsonian Institution," which deals with the quality and quantity of serviceable stone exposed along Seneca Creek; and two by Dr. David Dale Owen, entitled a "Report on the Baltimore county quarries" (12), and a "Report on the sandstones of the Potomac" (13). These give the first accounts by geologists and architects who visited the Maryland quarries to study their ability to supply good structural materials in large quantities.

Somewhat later W. R. Johnson (15) used the facts published in the preceding reports, together with information furnished by Robert Mills and by Mr. Dougherty in his comparison of the strength and durability of foreign and domestic building materials. His summary includes practically all of the pressure test results which had been obtained up to that time. Many discrepancies appeared which the author thought conformed to the law that there is "a direct relation between the power of resistance of a cube and the product of the *area of the base multiplied into the cube root* of that area." The law has not been accepted and the paper is chiefly of historical value through reference to papers which are now unobtainable, since many of the figures therein contained are not comparable with those obtained by the testing made in recent years under better conditions.

Prof. Chas. T. Jackson (16) visited the marble quarries at Texas in 1859 at the request of one of the operators, and on his return to Boston gave a brief account of the stone of the quarry visited, and drew comparisons between it and the stone from a neighboring quarry, which had been accepted for the extension of the General Post Office Building in Washington. The report is short, but contains figures

representing the specific gravity, weight per cubic foot, crushing strength and chemical composition of two dolomites and an "alum stone."

Tyson (17) was the first to give a systematic account of the materials grouped in this report as building stones or structural materials. This appeared in the appendix to his first report, entitled "Mineral resources of Maryland." The marbles are divided into three classes with the accessory "verde antique" and "Potomac marble" while numerous details are given regarding the granites, sandstones, slates, and flags, which are found in the state. Emphasis is laid on the availability of the tidewater granites and upon the slates of Harford and Frederick counties. The total discussion, however, is not more than eight pages long.

The state report of 1865 (18), prepared by a select committee of the legislature, gives a somewhat more extended account of the resources of the state, as then known. It represents a compilation of previous work rather than the results of new investigations in the area. It is based in great measure on the work of Tyson.

Professor Genth's (20) report on the Broad Creek (Harford county) serpentine, published in 1875, is perhaps the first special report calling attention to the availability of that stone for structural and decorative purposes. Although the geological interpretation of the area is open to question the paper remains of value from its descriptions of the stone and the chemical analyses therein presented.

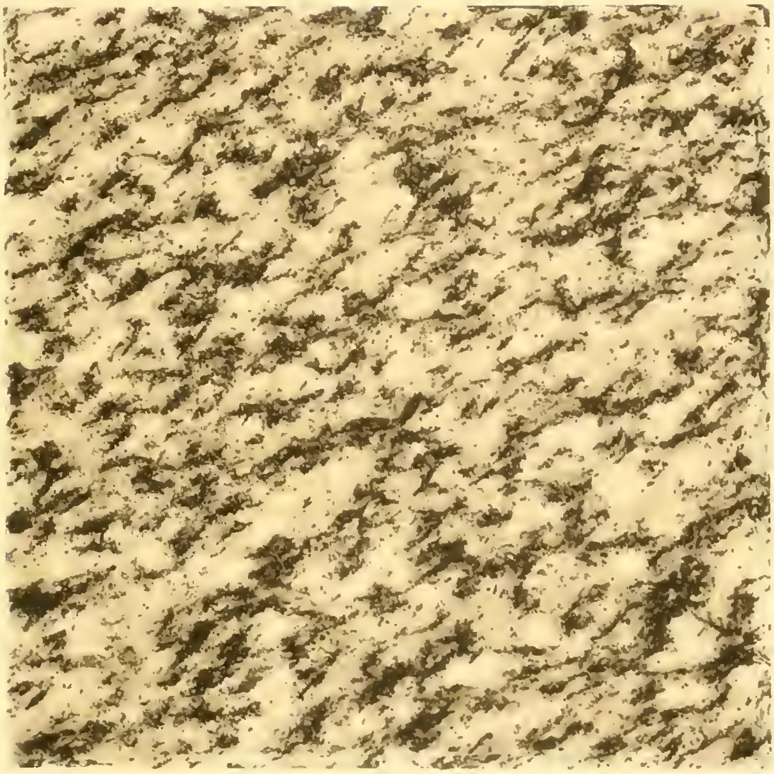
The well known "Report on the Compression Strength, Specific Gravity, and ratio of Absorption of the Building Stones in the United States" by Lieut. Q. A. Gillmore (21) deals almost entirely with the material from areas outside of Maryland, but does include the results of tests on Port Deposit granite.

Since the publication of the preceding report by Gillmore, the work, which has been done on the building stones of the state, has been conducted almost entirely by the Tenth Census Commission, the U. S. Geological Survey and the Johns Hopkins University. The report by the Census Commission includes many statistics (23) indicating the state of the industry in 1880, a "Description of the Quar-

ries and Quarry Regions compiled from notes of Messrs. Huntington, Monroe and Singleton" (24) and notes on the building stones used in Washington by Geo. P. Merrill (25). The last paper gives many dates at which Maryland material was used in the construction or extension of the Government buildings.

Somewhat later Merrill (26) published a handbook on "The Collection of building and ornamental stones in the U. S. National Museum," which had accumulated from the Centennial Exposition at Philadelphia in 1876 and from the Tenth Census collections of 1880. This book shows that about fifty specimens of the collection came from Maryland, and, that they represent many of the varieties which are described in the succeeding portion of this report. The author gives short summaries of the occurrence and character of these rocks under their proper headings. The work of the U. S. Geological Survey has been twofold, statistical and areal. The former has been conducted from Washington, and has led since 1883 to yearly statements concerning the output and state of various industries during the preceding year. This work has been carried on to a greater or less extent in co-operation with the Johns Hopkins University, and has led to a series of papers by Williams, Hobbs, Keyes, Grimsley and others, who have been occupied largely with the more purely scientific aspects of the problems. Williams' (27, 39) work deals particularly with the broader geological problems; Hobbs' published papers include detailed discussions of certain of the granites and gneisses in the vicinity of Baltimore; Keyes' shorter papers (31, 32) deal with the weathering and petrographical features of the granites, while his longer paper on the same subject gives more of economic interest. Grimsley's (35) publications on the granites of Cecil county deal particularly with the Port Deposit rock, and give many suggestions regarding the geology and economic features of the northwestern part of the county. Although all of these papers are devoted especially to the purely scientific questions, one may find many incidental references to the economic products, which have increased considerably the present stock of information.

Two works of later date deserve especial notice, viz., Keith's "Ge-



FOLIATED GRANITE

[illegible]

ology of the Catoctin Belt" (36) and "Maryland, its Resources, Industries and Institutions" (32, 33). The first gives the most exhaustive discussion of the formations of Frederick and Washington counties which has been published and furnishes many facts on the character and occurrence of the sandstones and breccias of the Newark formation, especially of those in the vicinity of Point of Rocks. The second, prepared by Williams and Clark and published under the direction of the World's Fair Commission, presents the facts more fully and more attractively than had been attempted previously.

Soon after the inauguration of the present organization an extensive reconnoissance was made of the resources of the entire state, and the results of this work were incorporated within an outline of our present knowledge of the physical features of Maryland, which appeared as Part III of volume one of the Survey reports. In this review are brought together concisely the more important facts regarding the building stones of the state, and an outline of the proposed investigation which has resulted in the present paper.

From the foregoing summary of the previously published literature it is evident that many men have written on those rocks of Maryland, which now serve as sources for structural materials. The amount of matter written, however, is small, and much of that extant possesses only an historical interest. Since the total volume of published information is small, and especially since many of the papers just enumerated are either out of print or generally inaccessible, it has been deemed best to incorporate the results obtained in the presentation of the new facts which have been acquired by the personal inspection of almost every quarry found within the state.

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THE QUARRIES OF MARYLAND.

Granites and Gneisses.

Granite is the broad family name that is applied to a large and common group of rocks, which are usually of a somewhat mottled light gray color, and almost always carry two minerals, quartz and feldspar, as essential constituents. Besides these, which make up the mass of the rock, there are dark colored iron-bearing minerals, such as black mica, or biotite, hornblende and occasionally pyroxene. Each of these may be evident to the eye without the aid of a lens. The microscope shows in addition many other minerals such as zircon, apatite or epidote which are of scientific interest, but of little economic importance as constituents of building stones, since they influence neither the appearance nor the wearing qualities of the material.

The foregoing minerals usually form irregular aggregates, in which the individual grains interlock in such a way that the cohesive strength of granite is relatively high. The constituent grains vary very widely in size, from individuals two or more inches in diameter to those which are scarcely separable with the unaided eye. The arrangement of the different mineral grains is irregular and without any prominent lines of distribution, when the granites are unmodified products of crystallization from a molten state. Subsequent action on the rock, however, through pressure or recrystallization, generally arranges the constituent minerals in some regular order, such as in parallel or wavy interlocking lines. It is in this way that many so-called gneisses or granite gneisses originate from granites, as at Port Deposit. True gneisses, however, usually result from the recrystallization of rocks laid down under water, and still retain their banded character. Since in the trade granites and gneisses compete for the same work, and since, when well sorted, there is little difference in their practicability for building purposes, they will be treated together in the present chapter, the differences between the two being shown in the order of grouping in the discussion of the principal quarries.

GEOLOGIC OCCURRENCE.

The granites and gneisses of Maryland are almost entirely limited to that portion of the state which has been described, in previous parts of this paper, under the title of the Piedmont Plateau, an area which consists of masses of ancient crystalline and partially crystalline rocks, which are of both igneous and sedimentary origin. These rocks since their formation have been subjected to many changes and alterations, which have produced a marked foliation or schistosity, showing a general trend from the northeast to southwest, with a moderate dip or inclination toward the northwest. The topography of this area is that of a moderately high and level plateau, which has been deeply eroded into a series of rounded hills and valleys by the streams that flow across it. The granites and gneisses of the plateau show no marked topographic features, although they are more prominent than the less resistant limestones, which occur scattered over the region. The industry based on the quarrying of the granites and gneisses is limited to a triangular area bounded on the east by the gravels and clays of the Coastal Plain and on the west by the less crystalline rocks on the western slopes of Parr's Ridge. Within this limited area there are included other crystalline rocks such as the serpentines, gabbros and peridotites, and in a few instances certain partially metamorphosed sedimentary rocks, such as the phyllites and roofing slates of Harford and Baltimore counties.

The complex geological structure of the Piedmont zone plainly shows that the rocks have been greatly disturbed at various times both prior and subsequent to the early base leveling of the region, when the crystalline rocks formed the foundations upon which the more westerly sediments were laid down. Some of the clastics became involved and infolded with the massives during the process of many foldings, and both were then subjected to the more or less intense dynamic action of the later orographic disturbances. The influence of the numerous intrusives, which are known to have broken through at various periods, operated still further to obliterate the original character of the rocks. The exact sequence of events has not been deciphered, although one speaking broadly may say that the gabbroic and dioritic types were the earliest to be extensively intruded.

These in turn were followed by the more basic non-feldspathic rocks, and then at different intervals the granite types appeared, breaking through all of the preceding series.

These granites as shown by the accompanying map (Plate VII) occupy several distinct areas along the eastern slope of the Piedmont Plateau. The largest of these is that extending from Sykesville to Washington, while the most important economically is the lenticular mass extending from Rising Sun through Port Deposit to the western side of the Susquehanna river. In all there are some fifteen areas where granite is prominently developed, and in at least five of these there are quarries of considerable economic importance.

DISCUSSION OF INDIVIDUAL QUARRY AREAS.

GRANITE.

Port Deposit.

The Maryland granite which is perhaps best known outside of the limits of the state is that quarried in the vicinity of Port Deposit. This town is situated on the Susquehanna river three miles above its mouth at Havre de Grace. It is one of the principal towns of Cecil county and has good railroad connections with Philadelphia, sixty-seven miles distant, Baltimore, forty-three miles, Washington, eighty-three miles and Harrisburg, sixty-five miles. It is possible also for light crafts to ascend the Susquehanna as far as the town and receive their loads directly from the quarry, thus furnishing water connections between the quarries and Philadelphia eighty miles, Baltimore fifty miles, Washington two hundred and twenty-five miles and Richmond three hundred miles. The gorge of the Susquehanna is emphasized by the wall-like mass of granite which skirts the river, from which it is generally separated by a narrow belt of meadow or marsh land. A mile above Port Deposit this rock wall becomes nearly perpendicular, and approaches close to the river. It was this protruding mass of the wall which first called attention to the valuable granites of the area, and it is at this point that the largest quarries are operated, the openings extending nearly to the water's edge. While some small quarrying has taken place in several spots, to gain room for buildings,

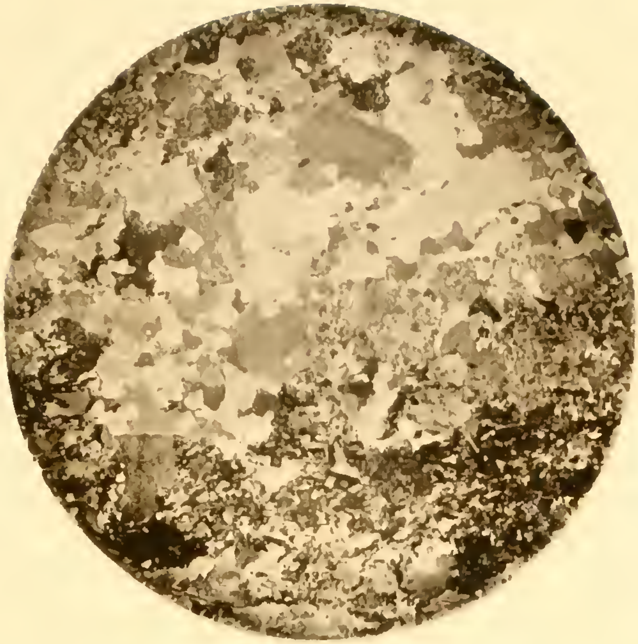


FIG. 1.—PHOTOMICROGRAPH OF GRANITE, PORT DEPOSIT. (MAGNIFIED TEN DIAMETERS.)

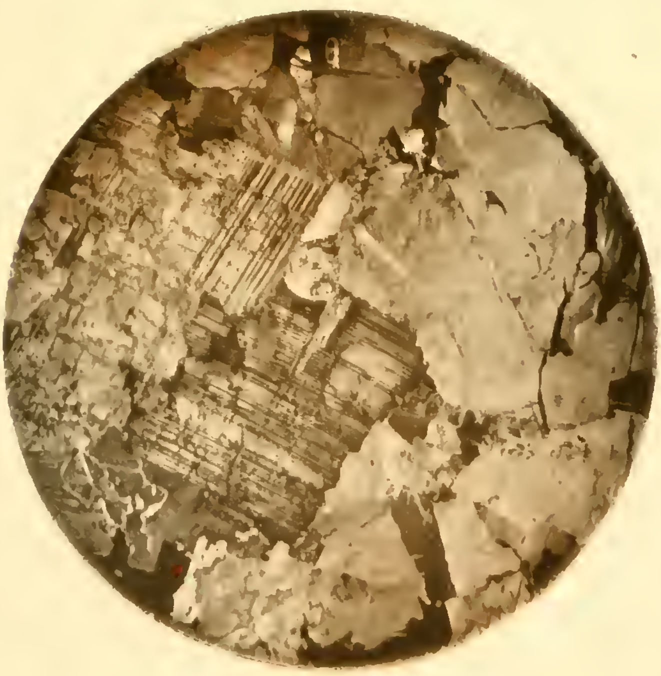


FIG. 2.—PHOTOMICROGRAPH OF GRANITE, ELLICOTT CITY. (MAGNIFIED TEN DIAMETERS.)

the industry at present is limited to the northern edge of the town, where the rock now stands exposed in an almost vertical wall measuring from the base to the top something over a hundred feet.

The value of the granites of this area was early recognized, and the rock was used by the settlers for the foundation of some of the oldest colonial dwellings. The industry arising from the quarrying of the rock is, however, of somewhat later origin. In the years 1816-1817 a bridge was built across the Susquehanna river at Port Deposit by the Port Deposit Bridge Company. During the process of construction the abutments for the eastern approach were made from stone quarried at the eastern end of the bridge, which is within the present corporate limits of the town of Port Deposit and not far from the site of McClanahan's quarries. For about ten years the opening so made was worked in a small way by Simon Freeze, who had supplied the materials used in the construction of the bridge. In 1829 the owners of the Maryland canal became interested in the quarry, and increased its workings. In 1830 the business passed into the hands of Samuel Megredy and Cornelius Smith, who still farther increased the scope and operations, and developed a considerable trade with Baltimore and other coastwise towns. Two years later Ebenezer D. McClanahan became interested in the granite quarrying industry through his brother-in-law Daniel Megredy, who was then a successful operator. McClanahan became the dominant factor in the local development and gradually increased the business until in 1837, from data furnished by Anthony Smith, Ducatel[1] estimated the annual output at from 12,000 to 15,000 perches. On the retirement of E. D. McClanahan the business was transferred to his sons, who are at present the principal owners in the Port Deposit company, which controls the local industry.

The quarries at Port Deposit, as shown by Grimsley in his work on the granites of Cecil county, are in rocks of igneous origin, which have been variously modified by severe dynamic action. This has produced a certain degree of schistosity which causes the Port Deposit granites to be taken at times for a gneiss rather than a granite. This foliation which is produced by the parallel arrangement of the black

[1] Ann. Rept. of the State Geologist of Maryland, 1837, p. 15.

mica flakes has a northeasterly trend nearly at right angles to the course of the river and a dip that is almost vertical. There is no marked banding in the rock, but the whole face of the quarry, which shows thousands of feet of surface, appears perfectly homogeneous, as though made up of a single rock. Through this mass there now pass several series of intersecting joints of which the most prominent approximately coincides with the northeast trend of the foliation, but which inclines somewhat to the dip of the foliation. A second set of joints runs almost normal to the first and is almost as sharp as those of the main series. A third set trending west of north is inclined 60° to the principal joints, while a fourth set, approximately horizontal, serves as bedding joints. The surface of the jointing plane is usually quite smooth and even, but the direction and distance between the parallel surfaces is not always constant. This produces a slight wedging in the blocks, which increases somewhat the cost of quarrying. On the other hand the smoothness of the joint surface frequently renders the rock ready for use in building without the intervention of the stone cutter, and allows the extraction of enormous nearly rectangular blocks. The expense of preparing the rock for use in the wall is accordingly reduced.

Although there are some half dozen series of jointing the rock a short distance below the surface is very compact, homogeneous, and strong, as is shown by the pressure tests of Gillmore, who found that the compressive strength of this rock was 13,100 pounds per square inch when tested "on edge," and still more clearly by the more recent tests just completed which show a crushing strength of over 80,000 pounds on two inch cubes. The incipient jointing planes, although so closely welded together as to show this great strength, are made use of by the quarrymen in trimming the huge monoliths and in cutting the smaller Belgian paving blocks, as the rock may be readily opened by means of wedge and "feathers."

The distance between the major joints, which varies from half an inch to several feet, is sufficiently great to allow the extraction of any sized block, which can be handled advantageously by the machinery and by the transporting agencies. It is usually considered

that the rock of the Port Deposit quarries is somewhat more easily worked than that at Frenchtown, which otherwise is indistinguishable. This difference in working arises in part no doubt from the greater age, better facilities for quarrying and handling and also from the more convenient position of dominant lines of working in the Port Deposit quarries.

The *texture* of the Port Deposit granite, or granite-gneiss is highly characteristic. The rock is composed of the usual granitic constituents, quartz, potassium, and lime-soda feldspars, biotite and accessory minerals. The most noticeable feature of the rock is the secondary gneissic structure, which is brought out by the arrangement of the shreds and flakes of black mica. This arrangement, which is better shown in the ledge and the hand specimen (Plate VIII) than in a thin section, is seen on examination to be due to small disconnected groups of mica flakes, which lie in approximately parallel lines. These lines are not straight or continuous, but are wavy and the flakes are disseminated or overlapping in such a way as to produce the well-known lenticular effect of gneiss. The color of the rock is a light bluish gray, which in buildings gives a bright fresh appearance at first and then gradually becomes somewhat darker through an accumulation of the dust and dirt in the atmosphere. Such a darkening of the rock produces a mellowed pleasing effect in structures situated in most of the cities. The roughness of the surface, however, and the abundance of the black mica render the appearance of the older buildings constructed from this rock somewhat sombre, if the atmosphere is strongly charged with dust particles. This is particularly true in cities where soft coal is used extensively without smoke consumers. On the whole the appearance of this rock is unusually pleasing. The effect in a building is somewhat variable according as the rock is laid on its bed or on its edge. The color on edge seems to be slightly brighter and more pleasing than when the stone is cut to lie parallel to the lamination.

The *chemical composition* of the Port Deposit "granite," as shown in the following analysis[1] of the specimen from McClanahan's quarry, is not normal for a granite. It is high in soda and lime and too low

[1] Made by Wm. Bromwell and given by Grimsley. Op. cit. p. 312.

in potash, and the excess of soda over potash shows that the rock is really a quartz mica diorite rather than a true granite. Since the amount of potassium feldspar is greater in many of the slides from other portions of the area, and since the rock is widely known as granite, this term is used in the present discussion in the trade-sense, rather than with the stricter scientific limitation.

Analysis of Port Deposit Granite.

SiO_2	73.69
Al_2O_3	12.89
Fe_2O_3	1.02
FeO	2.58
CaO	3.74
MgO	.50
Na_2O	2.81
K_2O	1.48
H_2O	1.06
Total	99.74

From the above analysis, the results of mechanical separations by specific gravity, and estimates based on a study of thin slices, Grimsley has calculated the proportionate mineralogical composition of the rock. The following percentages are thought to be representative:

Calculated percentages, from chemical analyses.	
Quartz	40.0
Orthoclase	9.0
Albite molecules	25.8
Anorthite	13.6
Biotite	9.7
Epidote	3.9

Percentages obtained by specific gravity separation. Sp. gr.		
2.65	(Quartz)	40.0
2.55–2.64, 2.67–2.8	Feldspar	45.0
Above 2.8	Biotite, Epidote,	15.0

A microscopic study of sections from the Port Deposit granite shows the presence of the usual granitic minerals, such as quartz, feldspar, dark and light micas, apatite, zircon, sphene, allanite, epidote, chlorite, hornblende, magnetite, garnets and occasionally calcite. The quartz is in relatively large sized areas, ranging from 0.5 mm. x 1.5 mm. to 3 mm. x 5 mm. With the aid of the microscope these areas are seen to be not single units, but composed of a great number of small quartz fragments, which have resulted from the crushing and recrystallization of the original granite during the period when the

McCLANAHAN GRANITE QUARRY, PORT DEPOSIT.

rock received its present schistose structure. These smaller quartz fragments are aggregated together by intricate interlocking sutures in a way which renders the rock less rigid and at the same time capable of withstanding fully as much pressure as an individual grain. The interstitial areas between the fragments of the coarser mosaic are filled with a mosaic of still smaller grains. Occasionally the quartz shows small inclusions of iron oxide, dust-like particles and "quartz needles," although it usually appears exceptionally free from them. After a study of several sections from the McClanahan quarry the present writer is inclined to think that the estimated proportion of the alkaline and plagioclase feldspar may better represent the character of the rock of the area, and that the figures obtained from the analysis and the slides indicate a greater amount of the more soluble plagioclase feldspar than the average run of the quarry. If the inference is correct the stone is stronger in its resistance to decomposition than the above analysis would indicate. The feldspars, like the quartz, occupy well defined areas and show the shattering and recrystallization into a mosaic, as a result of the dynamic forces which have modified the rock. These mosaics are much less frequent in the feldspars than in the quartz. The biotite occurs in aggregates of fine shreds, showing varying degrees of orientation, and is frequently associated with irregular grains or small crystals of epidote, sphene and allanite. The shreds and flakes are so small and so interlocked with minute grains of quartz, that they offer little increase to the weakness due to schistosity. The other constituents are so insignificant in quantity and so stable under atmospheric conditions that they do not influence appreciably the physical or chemical stability of the rock.

In any discussion or consideration of building stones, in order to appreciate the practicability of the rocks for large and permanent structures, it is necessary to know something of their physical properties. Among these the most important, as already shown in the previous chapter, are specific gravity, the ratio of absorption, the effect of freezing and thawing, and the compression strength. The specific gravity must be known in order to compute the weight to each cubic foot of the rock, which in turn indicates the amount of pressure im-

posed on the lower courses of the structure. Since almost all building stones are exposed to the atmospheric agents which influence them, it is well to know also what the varying conditions of temperature have upon a given stone. For example heating, due to the rays of the sun, causes the minerals to expand. Since the rate of such expansion is different for different minerals and even for different directions in the same mineral, there is unequal enlargement of the grains, and hence a loss in the cohesive strength of the rock. Other things being equal this change is greater in aggregates composed of many and vari-colored constituents. Again, if the rock is porous, the expansion of included moisture may rend the rock in freezing weather, so that it becomes necessary to know the amount of moisture absorbed by the rock, and so liable to expansion through frost action. The values obtained by Gillmore[1] on Port Deposit granite are as follows:

Position.	Cracked.	Strength of spec.	Strength per sq. in.	Sp. gr.	Weight of 1 cubic ft.	Ratio of absorption.	Remarks.
On bed.	......	79,000	19,750	2.720	170	0	Coarse, strongly dashed with black.
On edge.	33,000	52,400	13,100	2.720	170	0	do.
On bed.	......	66,000	16,500	2.720	170	0	do.
" "	....	60,000	15,000	2.720	170	0	Burst suddenly.

In the tests made during the search for a stone suitable to be used in the building of the Smithsonian Institution at Washington several Maryland building stones were studied, among which was included the Port Deposit granite. Dr. Chas. G. Page,[2] in his report on the action of frost on certain materials for building, gives as the specific gravity for the Port Deposit the figures 2.609, and as the loss by frost in grains 5.05. The method of investigation was the so-called Brard process, which consists in substituting the crystallization of sulphate of soda for the freezing of water.

The tests made[3] for the present paper are even more creditable to

[1] Gillmore, Reports on the Compressive Strength. Specific Gravity and Ratio of Absorption of the Building Stones in the United States. Rept. of the Chief of Engineers for 1875, Appendix II, p. 847. Also Republished 8vo. 37 pp. Van Nostrand, New York, 1876.

[2] See Bibliography No. 10.

[3] The conduction of this test was confided to Mr. Louis K. Shellenberger, Engineer of Tests, for Riehlé Bros. of Philadelphia, who rank high as specialists in the construction of testing machinery.

the rock. The specimens submitted were two inch cubes, carefully prepared and subjected to tests under the most uniform conditions. The results are as follows:

Simple Crushing.		Absorption, percentage of gain.	Freezing, percentage of loss.	Crushing after freezing.	
Crack.	Break.			Crack.	Break.
....	67,100	0.253	0.000	83,000	86,000
....	79,200	0.193	0.011	78,100	90,800
....	86,200				
....	101,540				

Tests made by Messrs. Booth, Garrett, and Blair, of Philadelphia, on a 2-inch cube gave the crushing strength as 84,730 pounds for 2-inch cubes, which is equivalent to 21,180 pounds per square inch.[1]

The results of these various investigations clearly show that the Port Deposit rock is strong enough to withstand all the demands made upon it by the pressure of superimposed stone work in structures, and to resist the various deteriorating influences of frost and atmosphere.

This view of the *durability* of the Port Deposit granite is well sustained by a study of its mineralogical and chemical composition, and the evidence of disintegration shown in the quarries and in old structures. The mineralogical composition indicates stability, as no mineral is present more liable to alteration than the lime-soda feldspar, which itself is not particularly prone to decomposition, although the first of the prominent constituents to yield to atmospheric action. Investigation at the quarries, where a considerable depth of decomposed rock is seen to overlie the more marketable material suggests the suspicion, that the Port Deposit granite will not withstand atmospheric agencies for any great period of time. This deceptive appearance arises from the fact that the crystalline rocks southward from Philadelphia have not been scoured and cleaned by the action of glacial ice as in more northern latitudes. Thus the overlying waste represents the decomposed products of several geological epochs, perhaps reaching back as far as Cretaceous time.

The number of quarries about Port Deposit has never been very large, although now and then attempts have been made to establish

[1] 18th Ann. Rept. U. S. Geol. Surv., pt. V, 1897, p. 964.

rivals to the large quarries which are at present operated by the McClanahan & Brother Granite Company.

Frenchtown.

At the eastern end of the high suspension bridge of the Baltimore and Ohio Railroad over the Susquehanna river there is a small quarry opened in a schistose granite, which is very similar to that worked at Port Deposit. This quarry was probably first opened during the construction of the railroad bridge,[1] but nothing of economic importance was done here until the firm of Wm. Gray and Sons of Philadelphia became interested in 1894. At this time the capital invested was about $8,000, a sum which represents but part of the present investments. No work of any particular moment was done by the present owners until the autumn of 1896, when the receipt of some moderate sized contracts encouraged the further opening of the quarry, which now bids fair to establish a well organized industry at Frenchtown. The only buildings of importance which have been built from the Frenchtown rock are the Cold Storage Warehouse and and an extension of the Baldwin Locomotive Works in Philadelphia.

The location of the quarry topographically and geologically is similar to that of the quarries at Port Deposit. The ground is stripped upon the side of a hill and the quarry has worked down to the level of the low bench, along which runs the Port Deposit and Columbia Railroad. The jointing of the rock is similar to that at Port Deposit, and there are here three prominent sets of joints intersecting approximately at right angles. Members of the same series are so placed as to facilitate working of the quarries and blocks containing 3,000 to 4,000 cubic feet might easily be obtained.

The texture of the rock like that at Port Deposit is coarsely granular, with a secondary lamination, and is adapted to all ordinary uses in general building, exterior ornamentation, curbing, paving, etc. It is possible, however, that this rock may be a little more "plucky" in working than the larger deposit farther north. This difference in the ease with which the stone is worked seems to be a temporary

[1] The main piers of the bridge are built of Port Deposit granite.

GRANITE-PORPHYRY

ELLICOTT CITY, HOWARD COUNTY

feature which may have disappeared before the publication of this report. Like the rock quarried at Port Deposit, that at Frenchtown frequently appears somewhat disfigured by small black patches or basic segregations of biotite, which often render the stone unavailable for the highest grades of ornamental work. The microscopical characteristics of this rock as well as the color and texture are the same as those of the Port Deposit rock already described. The quarries have not been worked long enough to indicate by the product the durability of the rock or to call for discussions of its specific gravity, crushing strength and other physical features. There is no doubt, however, that the rock will respond readily to all the demands made upon it for ordinary building purposes, and that it will resist any pressure or atmospheric influences which it would normally encounter. It weighs about 170 pounds to the cubic foot.

The quarry as yet is small. At the time it was visited in 1896 the total space excavated was scarcely more than 5,000 square yards. In 1897 the opening was fully twice that size. The transportation facilities are very good, the same as those at Port Deposit. The stone may be loaded directly on the cars for Philadelphia and Baltimore or on barges for these and other coastwise points.

Ellicott City.

The Ellicott City granite area consists of an irregular L-shaped mass, which has an extreme length of about five miles in an east and west direction and a breadth varying from one-half to two miles. On the north, west, and south it is bordered by a large gabbro area; on the east by gneiss. A considerable portion of the granitic area of this district is overlain by Neocene gravels (Lafayette Formation) and Cretaceous clays (Potomac Formation), thus concealing from direct observation much of the rock in question. The clastics, however, are quite thin, and consequently all the rivers and even the minor watercourses have cut their channels down to the more resistant crystalline rocks. The boundaries of the granites, gabbros, and other massive rocks are thus capable of being determined with nearly as much accuracy as if the sedimentary deposits were not present.

The quarries of Ellicott City are situated nine miles by road from

Baltimore and fifteen miles by railroad. They are located on either side of the Patapsco river in Baltimore and Howard counties, and the rock in which they occur extends on the eastern side of the Patapsco as far east as Ilchester, but on the western side only as far as Grays. The material on the Baltimore county or eastern side is a fine grained mass, with a decided foliation or gneissic structure. On the opposite side of the river in Ellicott City itself it is more uniform and granitic. Here it also has a porphyritic structure in consequence of the development of large flesh-colored crystals of feldspar which are disseminated somewhat irregularly through the rock, as shown in Plate XI.

The time of opening these quarries dates back probably into the last of the 18th century, but the details are entirely wanting. The beautiful appearance of some of the more uniformly porphyritic specimens early attracted attention, and in the earliest works which we have on this area, that by Dr. Hayden,[1] published in 1811, mention is made of these quarries. It is not certain whether the quarry on the Baltimore county side or the quarries of the Howard county side furnished the first material for Baltimore, but it is clearly evident from the character of the rock furnished for the Catholic Cathedral, that the gneiss was the more important rock at that time. Local tradition assigns the source of the stone sometimes to the Baltimore county side and sometimes to the Howard county side and the published information is equally conflicting and indefinite. When the Cathedral was constructed during the years 1806 to 1812 and subsequently from 1815 to 1821, the material was hauled from Ellicott City to Baltimore along the old Frederick road in huge wagons drawn by nine yoke of oxen. After furnishing the rock for this building, which must have been one of the most important stone structures in the United States at the time of its construction, the quarries evidently were worked only to meet local demands. In fact they have never since been of such relatively great importance. Dr. David Dale Owen, indeed, while studying the various building stones of Maryland at Cockeysville, Woodstock and Port Deposit, with the view of

[1] Geological Sketch of Baltimore, see Bruce's Amer. Min. Jour., vol. 1. New York, 1814, pp. 243-248.

FIG. 1.—GAITHER'S QUARRY, ELLICOTT CITY.

FIG. 2.—WEBER'S QUARRY, ELLICOTT CITY.

gaining all the information for the Smithsonian building, twice passed by these quarries and yet makes no mention of them. At the time of the Tenth Census the agent remarks that he "knows of no other place in the country where there are so many stone buildings in an area of the same size."

Of the quarries in operation at the present day those of Werner Bros. were opened as early as the beginning of the century. In 1872 Charles J. Werner reopened a quarry, which since his death in 1888 has been operated by his sons, who purchased in 1890 a second quarry, which had previously been opened by Robert Wilson. These quarries became of some importance in 1893, when one of them is spoken of as the principal Ellicott City quarry, although it is now producing little or no building stone except during the fall of the year when random rubble is quarried for local use. The output for the year 1896 did not aggregate over 200 perches. The most active quarry at the present is that operated by A. Weber (see Plate XII, Fig. 2). This quarry is situated on the Howard county side some distance below the station. The material has been furnished in recent years for some important buildings, as those of the Woman's College of Baltimore, but most of the material seems to be used for Belgian blocks, curbing and macadam.

The system of joints in the region under discussion are not regular, but intersect at varying angles and at different distances. In the Weber quarry there is one prominent series of bedding joints, which strikes in a southeasterly direction and dips at a low angle into the hill. Besides this principal series there are four or five others with more vertical dips and varying strikes, which free the rock in huge irregular blocks. The jointing is so prominent and so irregular that it modifies the manner of quarrying quite perceptibly, as the stone is first obtained in irregular masses and then worked into desired form by hand. Such a process increases the cost of operation, but at the same time furnishes considerable random rubble of a size suitable for ballast and rough road material. Across the river from the Weber quarry, in the opening worked by Gaither, the jointing is more regular and the face of the quarry is seamed into innumerable rhomboids several feet in diameter (Plate XII, Fig. 1).

The opportunities for shipment and drainage are good. Those of the Weber quarry are seldom excelled, as the opening is in the side of a hill so close to the tracks of the Baltimore and Ohio Railroad (main stem) that cars may be loaded simply by turning the derrick boom.

Probably no area of granite within the state shows as great variation in the texture and the character of the rock as that about Ellicott City. In the quarries on the eastern side of the river the rock appears quite schistose and homogeneous, and practically lacking in porphyritic crystals. Through it are scattered large patches or segregations of the darker minerals, which give to the rock the somewhat sombre effect displayed by the Baltimore Cathedral. These patches do not weaken the rock, though they render the stone less attractive. On the other side of the river, as has been mentioned already, the stone has a distinctly porphyritic character, which gives to it a mottled effect, well shown in Plate XI. The increased amount of feldspar brightens the rock and the distribution of the crystals adds detailed variety to the structures in which it is used.

The microscopic texture of the porphyritic type is shown in the reproduced photomicrograph (Plate IX, Fig. 2) where the grains are represented ten times their natural size. There is nothing particularly noticeable in the arrangement of the constituent since they unite with interlocking sutures, as already described in the discussion of the Port Deposit granites.

Woodstock.

Perhaps the best granite in Maryland for general building purposes is that which is found in the small area in the southwestern corner of Baltimore county near the railroad station of Woodstock, Howard county. Woodstock is situated on the main branch of the Baltimore and Ohio Railroad in the valley of the Patapsco twenty-five miles from Baltimore. It is a small country hamlet, but serves as the shipping point for the granites, which are quarried about one and one-half miles to the northeast. Within the area of the quarries is the small town of Granite, which was formerly known as Waltersville. According to the account of Mr. Arnold Blunt,[1] " boulders first attracted

[1] Maryland, its Resources, Industries and Institutions, Balto., 1893, p. 126.

GRANITE

WALTERSVILLE, BALTIMORE COUNTY

attention and were worked by several enterprising men from New Hampshire, who commenced their operations here about the years 1832-33. Among them were the names Sweatt, Riddle, Putney, Holbrook, followed by many others, among whom were the Emorys, Gaults and Eatons. The principal demand was at first by the Baltimore and Ohio Railroad for stone stringers, dressed to correspond to the flange and tread of the car wheels, and also ashlar, &c., for their bridge and culvert work."

Although prospecting has been carried on ever since, only two ledge quarries have been discovered, viz.: the "Waltersville" and "Fox Rock." The former is the principal one, and was at first called the "Branch." This rock developed into a fine ledge, surpassing all the granite around in quantity, quality and easy access, so that all the boulders in which Sweatt, Putney and Riddle were interested were at once abandoned. After working it for a year or two Putney and Riddle obtained a lease of this quarry for twenty years in August, 1835, from the owner, Captain Alexander Walters, to whose family this quarry has belonged for more than a century. It is called in the lease and is still known as the Waltersville quarry, although the name of the village of Waltersville was changed to Granite about 1873-74, when the first post-office at the place was established. The lessees went to work vigorously, and besides many other improvements, built a railroad two miles long to connect with the Baltimore and Ohio at Putney and Riddle's bridge, about one mile east of Woodstock. Their first contract of importance was furnishing stone for the Baltimore Custom House. They, however, continued the business only a few years. Extravagance and mismanagement caused the failure, and they were succeeded by Edward Green and Joshua B. Sumwalt, under the firm-name of Green & Sumwalt. The senior partner dying about 1849, he was succeeded by his son Frederick, and the firm became Sumwalt & Green, who conducted the business until 1865, when Attwood Blunt, whose wife owned the property, took charge and continued the business until 1871, when the quarry was leased to Ansley Gill and James McMahon. After a lapse of about sixteen years, the firm was dissolved by the death of

McMahon. Mr. Gill continued the business alone for a short while, when he associated with him Wm. H. Johnson, of Baltimore, and they soon after formed with George Mann, Hugh Hanna, Messrs. Grey & Sons, of Philadelphia, and Mr. Hamilton of Baltimore, a joint stock company, calling it the Guilford and Waltersville Granite Co. This company is now conducting the business.

The rock from the Woodstock area was early used, as indicated in the preceding sketch, but the first published account of it which attracted attention was that by Dr. David Dale Owen.[1] In his report to the Building Committee of the Smithsonian Institution he says: "During the examination of structures and monuments of Baltimore marble, both in Greenmount cemetery and in the city of Baltimore, with a view to ascertain the durability and facility of working this material, I was so much struck with the beauty of some of the granite vaults and fronts of buildings that I determined to visit the quarries from whence this material was procured. . . . Accordingly I stopped at Woodstock, 16 miles beyond the Relay House, and inspected carefully the Waltersville branch and the Fox Rock quarries in this vicinity; both of which are well opened, and afford a good opportunity of judging the quality and extent of this formation.

"For about a mile square at this locality is an outburst of quartzose granite of magnificent quality, both as regards beauty of appearance, compactness of structure, and uniformity of color, texture, and composition. I have never seen anything superior in this country; indeed, I doubt whether it can be excelled in any country. . . .

"Fully to appreciate the quality of this granite, the quarries themselves must be visited, and the huge blocks in mass inspected as they are removed from their original bed. There, one may see a perpendicular face of nineteen feet presented to view, extending twenty, thirty, and even forty or fifty feet, without a seam or flaw, or the slightest variation in hue. A mass of forty or fifty tons weight may often be seen severed from the parent rock, by the simple but effective means of small iron wedges. . . . The Fox Rock quarry is thirty-six feet from top to bottom, where now excavated. It might be worked

[1] Report of the Board of Regents of the Smithsonian Institution, Jan. 6, 1848. Senate Doc. 30th Congress, 1st Session. Miscl. No. 23, pp. 31-32.

FIG. 1.—WELLER'S QUARRY, GRANITE, BALTIMORE COUNTY.

FIG. 2.—GUILFORD AND WALTERSVILLE QUARRY, GRANITE, BALTIMORE COUNTY.

some fifteen or twenty feet lower before being incommoded by water. Mortar adheres with such force to this granite, that, when fairly set, it requires as much force to separate the substance of the granite as to detach the mortar from the face.

"On the whole, the inspection of these granite quarries has impressed me with the belief that no locality can furnish a superior quality of granite, and that it cannot be surpassed for strength and durability by any building-material in the world."

The letters which accompany this report show that in 1847 the firm of Sumwalt, Green & Co., evidently composed of Edward Green and Joshua B. Sumwalt and his son Frederick, carried on the business, and the size of the quarries, as indicated in the remarks of Dr. Owen, shows that the business had already reached a considerable importance. Perhaps as the result of this report by Dr. Owen, the contract was granted for furnishing the foundation stone, which was used in an extension of the Patent Office Building constructed in 1849, and the Postoffice Building, in 1855, although some of the Woodstock granite had been used in the general Postoffice before 1817.[1]

The granite mass as indicated by the map forms a more or less oval, isolated area of granite extending scarcely two miles northeast and southwest and a mile northwest and southeast. Although so small, it is one of the most important economic areas within the state. This mass of granite, which is evidently intruded into the gneisses, is entirely enveloped by them and sends no dikes or apophyses into the surrounding rock. That the gneiss is really older than the granite is shown by the great number of inclusions found within the latter. These are chiefly of gneiss, and they occur often in huge irregular blocks six to eight or even ten feet in size, showing narrow rims due to contact metamorphism. They are beautifully puckered and wrinkled and being much richer in ferro-magnesian silicates than the granite itself, their irregular outlines contrast sharply with the lighter background. (The darker portion of the large block in the center of Plate XIV, Fig. 2, is included gneiss.)

The most marked feature of these quarries, especially in the Waltersville quarry (Plate XIV, Fig. 2), is the sharp definition of the

[1] Loc cit. p. 41.

systems of vertical and horizontal joints which are so prominent and so persistent in their horizontal extent, that they at first glance give the impression of stratification. They strike approximately north 60° east and dip at an angle of 10°-15° to the northwest. The joint faces are not planes, but are curved more or less irregularly. The figures given represent the general strike and dip as seen in the Waltersville quarry, but even these somewhat generalized values are not persistent over the entire area, for in the center of the Weller quarry, which abuts upon the Waltersville quarry on the west, the strike and dip changes completely within the distance of a few feet. This irregularity in the joints has caused considerable trouble in the quarrying, although when visited the ledge worked was well exposed, and the blocks were large and easily obtained. The accompanying figure (Plate XIV) shows how large slabs and blocks may be freed at little expense. The piece in the center of the picture has been separated from the ledge at the back by a series of wedges, while it was only necessary to use a bar to pry the mass from the ledge beneath. There are fully five or six series of joints which are distributed without any marked uniformity through the mass. Besides the main horizontal joints there are others at a slight inclination, which continue for a short distance and then die out. The vertical joints show several planes oriented in different positions and showing variable dips and uneven surfaces.

This jointing is sharply brought out by the weathering of the rock. "The quarry ledge has the appearance of a great wall of cyclopean masonry, layer upon layer of huge blocks rising one upon another with the regularity and precision of human workmanship. The separate blocks are more or less oblong in shape, and often measure 15 to 20 feet in length and from 2 to 8 feet in height. They are all more or less rounded, the spaces between the different boulders being filled with incoherent granitic sand, derived from the decomposed edges and the sides of the blocks. It is quite evident that the granitic mass was originally everywhere jointed, and that atmospheric decay took place much faster on the edges and corners than on the flat sides of the great fragments, thus quickly rounding and forming them into boulders like those found throughout drift areas. The sandy matrix is

DETAILED VIEW, WELLER'S QUARRY, GRANITE.

usually from 5 to 10 inches in thickness. The interior of the boulders is perfectly fresh, and affords the best of rock for building purposes. As decomposition progresses the amount of interstratified sand greatly increases, and the blocks become proportionately smaller."

This method of weathering facilitates the early workings in a quarry and so brings the rock into notice, but there is necessarily a great deal of waste and considerable expense in bringing these boulders into rectangular form unless there are well defined seams or a " grain " running through the rock, as is the case at these quarries. The grain of the rock is so marked that it cannot fail to impress any thoughtful observer who visits the quarries.[1]

The jointings in the Fox quarries are not as strongly brought out by weathering as they are in the Weller and Guilford and Waltersville quarries although the different series are distributed in about the same manner. At the time of inspection, these quarries, which are operated by the Gaults, were not in active operation, although considerable material suitable for furnishing Belgian blocks and random rubble was scattered about the pits.

The appearance of the Woodstock granite is well represented in Plate XIII which reproduces the polished surface in natural size. The color of the rock is bright gray, with something of a luster imparted by the quartz and the unaltered feldspars, the latter often giving an additional faint pink tone. The mica occurs in evenly disseminated fine black flakes which emphasize the grain of the rock and only slightly subdue the bright fresh aspect of the stone. The size of the constituent grains which varies from 0.05-0.2 inches in length, and from 0.01-0.10 inches in breadth, for quartz and feldspar, is little marred by the less resistent mica wearing away and leaving small depressions, that are scarcely discernible to the naked eye. The polished surfaces, such as are represented in the plate, are darker than the rough or ashlar finished stone.

The chemical composition of the rock, as indicated in the following analysis by Mr. Hillebrand,[2] shows the rock to be somewhat siliceous

[1] See ante p. 152 and Plate XIV, Fig. 1.

[2] Report of Work done in the Div. of Chemistry and Physics. Bull. No. 90, U. S. Geol. Survey. (1890-91) Washington. 1892. p. 67. E.

and yet particularly rich in lime. This marked increase in the percentage of CaO is explained by the presence of considerable allanite and epidote in the rock. It is therefore not a source of contamination, for the epidote is particularly stable under atmospheric conditions. The percentage of the alkalies is moderately high, while the iron and magnesium content is very low. The rock, accordingly, possesses great durability and power of resistance toward atmospheric decomposition.

SiO_2	71.79
Al_2O_3	15.00
Fe_2O_3	0.77
FeO	1.12
CaO	2.50
MgO	0.51
K_2O	4.75
Na_2O	3.09
H_2O	0.64
	100.17

The tests to which specimens from the Waltersville quarries have been subjected show the rock to be all that could be desired for strength and durability. The strength of the stone is several times that of brick, and the percentage of absorption is very low, showing that the stone can withstand both pressure and the deteriorating action of frost. The figures obtained are as follows:

Simple crushing.		Absorption.	Freezing.	Crushing after freezing.	
Crack.	Break.	Percentage of gain.	Percentage of loss.	Crack.	Break.
79,700	85,700	0.258	0.011	79,400	102,200
79,200	83,420	0.232	0.029	86,800	90,300

Guilford.

Perhaps the most attractive stone found within the state is that which is quarried at Guilford in Howard county, about five miles northwest of Annapolis Junction, on the Little Patuxent river. This granite early attracted attention because of the uniformity and fineness of its grain, its light color and pleasing effect. Although the area furnishes excellent monumental and building material it is unfortunately situated some miles north of the Baltimore and Ohio Railroad, a circumstance which has delayed such a development and recognition

of the rock as the material deserves. At present there is a sidetrack which runs from the Baltimore and Ohio Railroad to Savage Factory only two miles distant. This distance, however, with the necessary hauling, is sufficient to render successful competition with more favorably deposits somewhat doubtful.

The quarries at Guilford were originally opened about 1834, and were worked almost continuously from that date until the outbreak of the civil war in 1860. During the succeeding twenty-five years the operations were of little account, and little work was done until the Guilford and Waltersville Granite Company attempted to develop the industry in 1887. This effort lasted but a short time as all of the machinery was removed from the quarries in 1889. The industrial life of the district has been revived somewhat in recent years by the operations of Messrs. Matthew Gault and Sons, who commenced work in 1893, and by Messrs. Brunner and White, who opened a quarry of superior quality in March, 1895.

The Guilford granite is bordered on the north and west by the Piedmont gneiss and on the east by the gabbro. It is also in part covered by the gravels and clays of the Potomac. The jointing of the rock is sharp and usually regular, the individual planes being sufficiently far apart to allow the quarrying of blocks of any reasonable size; at the same time they aid materially in the freeing of the stone.

The rock of this area differs from all of the other granites of the state in the persistent presence of both light and dark colored micas. Thus, according to the German classification, it is the only "true granite"[1] in the state. Other granites may have muscovite as a constituent, but it is not so abundant or typical as in the present instance. Both of the micas are products of the original crystallization of the molten rock magma, and they are frequently in parallel growths. The biotite, which is especially rich in iron, possesses a very dark color, but shows no evident disintegration or decomposition. The feldspar

[1] The use of this term in previous papers on the granites of Maryland has led to some misunderstanding on the part of quarrymen. In this petrographical sense as applied to granites "true" has not meant that all of the granites of Maryland with this exception are "bastard" granites, but it has only meant that this granite corresponds to the "zwei-glimmer" or "echte granit" of the German classification.

is almost entirely microcline, which shows the cross-twinning very clearly, and appears clear and fresh with very few included flakes or small cystals. These microclines form the largest individual areas in the rock mass, sometimes reaching 0.15-0.2 of an inch (4-5 mm.) in diameter, while the clear transparent grains of quartz average less than 0.01 of an inch (.03 mm.). The individuals are interlocked in a mosaic, which indicates that the rock can well withstand any pressure to which it may normally be subjected. The mica flakes are small and evenly disseminated, so that they do not injure the polish which may be given to the rock in preparing it for monumental purposes.

Minor Areas.

Besides the five areas already described there are several other granite masses within the state, as indicated by the map, which have been worked from time to time to supply the local demands, and occasionally with the hope of bringing the stone into commercial importance. Of these smaller masses which have been quarried spasmodically the most important is that of *Dorsey's Run* on the Baltimore and Ohio Railroad between Ellicott City and Woodstock. The stone of this area was first quarried for use on the Baltimore and Ohio Railroad to protect the roadway from the encroachments of the Patapsco. These and subsequent operations have developed two or three quarries which have furnished about 10,000 cubic feet each, since they were first opened. The proximity to the railroad has been of advantage and efforts were made in 1893 by Mr. W. B. Gray of Baltimore and Messrs. Peach and Feenay of Woodstock to develop a trade in curbing and paving blocks. The quarries at the time of writing, however, have suspended operations. The ledges furnish blocks of 40 or 50 cubic feet, but the product seems to be overshadowed by that of the neighboring quarries in Ellicott City and Woodstock.

In 1888 Mr. W. F. Weller of Granite leased a quarry near *Sykesville*, and began somewhat later the quarrying of Belgian paving blocks, which was continued for some year and a half. At the present time this quarry is not in operation, and no others are at present worked in the vicinity.

On the southern prolongation of the Sykesville mass near Garrett

FINE GRAINED GRANITE.

[illegible]ORD, HOWARD COUNTY

Park and Brookville is a quarry operated by John A. Riggs, which was probably first opened about the beginning of the century, from which time it was occasionally operated in a small way up to 1881. The total amount of stone extracted, however, does not exceed 1000 perches. No large stone can be obtained from the present opening, as the rock is much broken into blocks, which contain scarcely 20 cubic feet. This opening, however, is in a poor place and the best stone has apparently not yet been reached. Since the distance from the railroad renders this rock unavailable for city demands it will probably never be of more than local importance. Some twenty-five years ago a second quarry was worked at Brookville in rock which was good for local requirements. This was opened in 1850 and some 1000 perches of rock were obtained between 1850 and 1870. The granite exposures at Garrett Park embrace several small outcrops of which the best are those along Rock Creek. At several of these small exposures, quarries have been opened and worked from time to time to supply the local demand.

Probably the most extensive operations carried on in Montgomery county are those near Cabin John, in a quarry operated by Mr. Gilbert. This quarry was opened about 1850 and there have been excavated probably 1,500,000 cubic feet. The rock is a schistose granite rather dark gray in color, and suitable for general building and road metal. In the quarry there are three prominent sets of joints, which, however, are so placed as to permit the quarrying of large blocks. Already pieces containing 1000 square feet have been obtained. The mode of transportation from the quarry to Washington, a distance of six and one-half miles, is the Chesapeake and Ohio Canal, which has rendered the location so available that the rock has supplied some of the demand for foundation stone. At the time when the quarry was visited operations had been suspended and the machinery on the ground was unused and going to ruin.

At Franklinville on the Little Gunpowder, three miles north of Bradshaw's Station, are exposures of a schistose granite resembling that quarried at Port Deposit although somewhat darker and even more schistose. This rock has not been quarried as much as its position and character might warrant. It is owned and worked by the

Cotton Duck Factory Co. It has supplied the local demands and there have been quarried about 1000 perches a year for the last seven or eight years. Large curbing blocks might be obtained easily, as blocks 11′ x 2′ x 1′ have been quarried. The opportunities for operating are good, as freedom from water and large dumping grounds are features of the location. The distance, however, from the railroad might be a serious drawback.

In the town of Benson, Harford county, there is a small opening for granite, where quarrying was first carried on in 1885. The output is small, not reaching 1000 perches a year, and yet from this locality was furnished the material for one of the churches in Bel Air. The quarry, which is owned by Mr. L. Amoss, is situated near Winter's Run on the Harford pike and was never opened with the intention of operating it extensively. The stone is in boulders and is easily worked by hand. On exposure it becomes lighter and more pleasing in color.

Near Baldwin's Station, Cecil county, is a small quarry of schistose granite, which supplies some of the local demands of Elkton, Maryland, and Newark, Delaware. This quarry is on the farm of Levi L. Hammond and was opened in the year 1842. The operations are small, the average yearly output reaching perhaps 2000 cubic feet. Blocks containing 1200 feet have been obtained, and even larger might be quarried, if the facilities for handling were at hand. The quarry is only worked occasionally for building stone, which is sold by the perch.

GNEISSES.

Certain of the more uniform and compact gneisses furnish first-class building material and many quarries have been opened in the areas where the demand is great and the expense of handling and transportation is fairly low. These quarries are especially noticeable in the vicinity of Baltimore where all of the conditions are fulfilled. The gneisses of the area, represented on the map, show great constancy in their mineralogical and textural composition. They are composed of alternating bands of fibrous to micaceous hornblende, biotite and chlorite schist between lighter colored more or less feldspathic quartz-

schist. The dark ferruginous bands break down readily and are not used at all as structural material, but are discarded as waste. The best material comes from those portions of the lighter bands which are composed almost wholly of quartz, the prepared blocks differing but little from those made of a well characterized quartzite. The rocks are rather strongly bedded in slabs from one quarter to three feet in thickness, and are thus more easily worked than the hardness of the rock might at first suggest. The areal distribution of the gneisses, as represented by the accompanying map, clearly shows that the structure of the area is intricate and complex. The general trend of the formation is north-northeast and south-southwest, with a similar strike for the foliation, which usually dips to the northwest at a high angle. In the region adjoining Baltimore the structure, as indicated by the contacts and the position of the foliation, is still more complicated by sharp folds, faults and intrusive masses. Beginning east of Catonsville the strike of the foliation (probably nearly the same as the original bedding) becomes more and more northerly, until at Woodberry it turns quite rapidly to the east and southeast crossing Jones' Falls south of Hampden with a trend somewhat north of east. The strike about Lake Montebello (Baltimore city) seems to radiate in a fanlike manner to the northwest, north and northeast. About Lake Roland and the Bare Hills this structure becomes even more confused, and yet preserves a general parallelism with the gabbro-gneiss boundary.

The quarries about Baltimore are grouped around two centers, Jones' Falls and Gwynn's Falls, on the northern and western sides of the city, the location being determined by the facilities afforded by the shape of the country for opening and working the quarries on a horizontal plane. This method of working decreases the cost of handling the stone, avoids any expense or difficulties because of water and often furnishes a convenient and cheap dumping ground away from the rock bed which may be worked in the future.

Jones' Falls.

The quarries on Jones' Falls were originally opened at some distance from the city, as they were in operation probably before the beginning

of the present century. The first mention of them is found in a rare journal[1] published in Baltimore in 1811, where the following words occur in a description of the geology of Jones' Falls: "Immediately above this [a pegmatite dike] it [the gneiss] assumes nearly the texture of the first mentioned, being fine, hard and compact, and gradually passing through the above transitions, until, at one mile and a half from Baltimore, it acquires a texture, such as to render it highly valuable and useful in various branches of masonry, and as such, is here quarried on both sides of Jones' Falls, to considerable advantage to the proprietors."

The first quarries opened were probably situated on the *right* bank of the Falls about where the Mount Vernon shops now stand, and were operated more or less continuously until the building of the Northern Central Railroad, about 1830. The quarries on the left bank of the stream have been in almost continuous operation from the time of their opening until now. It has been difficult, however, to gather any information regarding the various operators who have been interested here.

The occurrence of the quarries is all that could be desired. The rock is clearly bedded in sheets, ranging in thickness from four or five inches to five or six feet. These sheets extend with almost no break for considerable distances, as is shown in the accompanying view of the quarries leased by Messrs. John F. Curley and John G. Schwind. The sharp light lines extending diagonally across the main sheet from left to right are small faults with a throw of a few inches. These sheets are rendered workable by two series of joints at right angles to each other, situated at favorable intervals. These are also supplemented by a "grain" in the rock, which is at right angles to the bedding and nearly parallel to one of the planes of jointing. From this distribution of the lines of weakness, it is possible to free large blocks from the bed and then, if desired, the slabs may be separated readily into smaller blocks. The angles of inclination between the planes of jointing, bedding and grain do not vary widely (usually 10°-15°) from 90°, so that the stone may be squared without great cost. No dynamite is used in the quarrying, but occasionally charges

[1] Loc. cit. pp. 255-271.

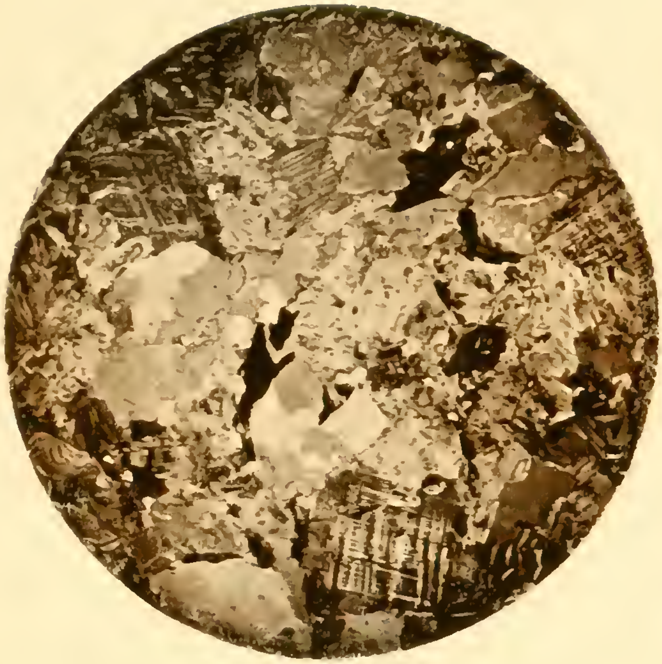


FIG. 1.—PHOTOMICROGRAPH OF GRANITE, GRANITE. (MAGNIFIED TEN DIAMETERS.)

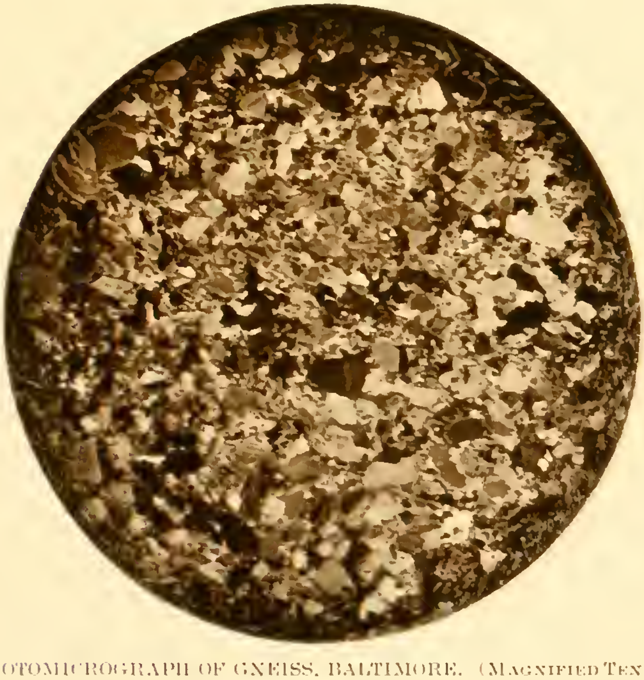


FIG. 2.—PHOTOMICROGRAPH OF GNEISS, BALTIMORE. (MAGNIFIED TEN DIAMETERS.)

of powder are employed to loosen the rock and thus render it easily separable along its joints and grain with the "plug and feather" wedges.

The inclination or dip of the beds also facilitates the quarrying. It is usually about 45° to the northwest, so that the freed blocks may be easily handled. There are two methods of utilizing this dip. In the Peddicord quarry on the Falls road the operations are carried in horizontally *along* the strike, and then the various beds are worked from the top and side. In the Curley-Schwind quarry, where the same beds are exposed, the "head" is first driven in *across* the strike, and then the beds are worked along the strike.

The *texture* of the different sheets varies considerably, but the first quality rock runs quite uniformly. It always shows a lamination parallel to the original sheeting and should therefore be laid on its bed in structures. The quartz and feldspar grains are of approximately the same size and unite with the small mica plates to form a uniformly textured rock of dark gray color. The different beds vary somewhat among themselves in the size of the grain, in the relative amount of quartz and feldspar and in the amount of lamination. As is true of many sedimentary gneisses, this difference in the dark and light bands is so well defined that the quarrymen by a little sorting may furnish material which will run uniformly for individual shipments. There will, however, be some difference between different shipments, unless considerable care is exercised by the quarry master.

The *color* of the rock has been given already as dark gray, but from this there are many variations, with a range from very light gray to a dark sombre, vitreous blue-black. The variation depends upon the amount of feldspar and mica present. If the rock is composed almost entirely of clear, vitreous and pellucid quartz grains the rock is usually dark and cold whether there is much mica present or not. When feldspar is present or the grain of the rock becomes fine or saccharoidal the color of the rock is brighter and more pleasing. The amount of mica present in the feldspathic fine grained rock seems to have a greater effect on the color than is the case in the more quartzose varieties. This constant blue-gray tone in the color of the rock

has led to the application of the local term "blue stone," which is current among the quarrymen and is often introduced into contracts.[1]

The chemical composition of the gneiss is so variable that single analyses cannot represent the character of the whole mass. A fair representation of the composition of the lighter colored gneiss would show the silica rather higher than the average. A microscopical study of these same lighter bands, which are used the more extensively, show that the constituents do not always interlock, although there has been considerable growth of the quartz grains since the rock was formed. These are indicated by the light veins about many of the grains in Plate XVII, Fig. 2. Most of the grains are somewhat rounded, suggesting that the gneiss is of sedimentary origin, and the interstitial spaces are filled with more finely comminuted fragments of quartz, feldspar and secondary minerals. Among the last are epidote, garnets and occasionally fibrolite, cyanite and staurolite.[2]

The chemical and mineralogical composition of the Jones' Falls rock show that the individual constituents are not liable to decompose readily and that there are few minerals occurring as accessory constituents which really vitiate the rock. On the other hand, the crushing tests show that there is a much more marked tendency to physical disintegration in certain directions. The rock to be serviceable must, therefore, be placed in the wall in certain positions only. The results of the tests are as follows:

	Crushing.		Absorption. Percentage of gain.	Freezing. Percentage of loss.	Crushing after freezing.	
	Crack	Break.				
Quartzose layers ("Blue Stone.")	66,700	70,140	0.197	0.028	80,118	118,000
	85,940	96,300	......	......	......	......
Feldspathic layer ("B. granite.")		94,200	1.116	0.052	63,060	84,220
	78,600	103,500				

[1] This term "blue stone" is a popular one which is applied to different rocks in different localities; e. g. in the District of Columbia it signifies a mica schist; in Pennsylvania and New York a blue-gray sandstone; in Ohio a gray sandstone. This last usage has beeome so common in the trade that it is hardly proper to call the Baltimore gneiss a "blue stone."

[2] On the faces of the joints where there has been a little space after the movement of the rock there are often found haydenite (chabazite), laumonite, harmotome (or phillipsite?), stilbite, beaumontite (heulandite), siderite, pyrite, barite, haloysite, epidote, garnet, and tourmaline. See Notes on the Minerals occurring in the neighborhood of Baltimore by George H. Williams. 17 pp. Baltimore, 1887.

The quarries show that the rate of decomposition and disintegration is really very slight for gneisses standing at so steep an angle that the surface waters may saturate the rock with great freedom. There is, of course, considerable stripping required in some places, but when it is remembered that these rocks, unlike the rocks farther north, retain the evidences of exposure to the destructive agents of the soil and atmosphere since Cretaceous time, certainly several million years, the amount of weathering seems insignificant.

The most serious drawback is not in any possible line of weakness, but in the color. When pieces of gneiss from different layers are intermingled without any care or arrangement, the effect is not pleasing, but quite the reverse. There is current an impression that the material for the Cathedral in Baltimore came from the Jones' Falls quarries, a view which is scarcely in harmony with the statement of Mr. Robert Gilmor, Jr.,[1] in which he describes how the material was brought from the Falls of the Patapsco about ten miles out on the Frederick pike. Part of the material may have been furnished from the nearer source, but under these circumstances it would probably have been from the quarry on the right bank and not from any of those on the left bank, since the former was then the more important source of material. Moreover, certain buildings such as the old Court House, portions of the Jail and some of the buildings at the Woman's College show that the rock may give a pleasing effect in structures. The demands at the present time are satisfied by higher grade material, such as the Port Deposit or Woodstock granite, and a large part of the gneiss quarried is employed either for foundations and paving or as a backing for the more pleasing stone.

The quarries in operation at the time of inspection by the writer were the Peddicord, the Curley-Schwind, and the Atkinson.[2] Of these the Peddicord is the largest, showing an excavation of over seventeen million cubic feet; the Curley-Schwind shows about three million, and the Atkinson something over a million cubic feet.

[1] Bruce's Amer. Min. Jour., vol. i, New York, 1814, p. 232. See p. 126.

[2] The "Atkinson" of the topographic map is now the Peddicord and Atkinson is working a smaller quarry a little farther northeast beyond the Curley-Schwind quarry.

Gwynn's Falls.

The work in the area west of Baltimore along the Gwynn's Falls and Gwynn's Run did not begin for some fifty years after that along the Jones' Falls, since the product lay to the west of the growing town and was separated from it by a series of ridges which increased the cost of transportation. As the city extended westward, the supply from Jones' Falls became more expensive, and that from the small openings along Gwynn's Falls cheaper. The real work of the area began about 1850 and has continued without any marked abatement to the present time. The largest quarries in this part of Baltimore are operated by John G. Schwind, lessee and part owner of the large quarries on Edmondson Avenue, which are perhaps the largest and best equipped of any of the openings about the city.

As shown upon Plate XVIII, Fig. 2, the rock of this quarry is a gneiss, inclined at an angle of 30° and dipping to the northwestward. The general strike of the beds conforms to that of the area, which is north 45° east. As is the case of the Jones' Falls quarries, the rock exposed in the quarries varies considerably, and furnishes two marked grades of material, one which is almost pure quartz resembling a quartzite and the other a much more feldspathic and micaceous aggregate very similar to the granite, but showing a greater or less perfection in its bedding.

In the quarry face the individual beds range in thickness from two to four feet, each showing great uniformity. The workable ones are clearly separated from each other, either by well defined bedding joints or by beds of inferior quality. Across each sheet are at least three sets of joints nearly at right angles to each other, which greatly increase the ease with which the material is extracted. The joints are separated from each other by distances ranging from a few inches to several feet, so that while facilitating the work they do not render the rock inferior, because of too great frequency. It is possible to obtain blocks of any size within the range of economical handling. This limit seems to be reached in blocks of seven or eight tons. The hoist in use, however, is capable of handling ten ton blocks. The product of these quarries is scarcely distinguishable from that already described as characteristic for those of Jones' Falls. Like the latter the

FIG. 1.—CURLEY-SCHWIND QUARRY, BALTIMORE.

FIG. 2.—"EDMONDSON AVENUE" QUARRY, BALTIMORE.

range in material is very wide. All of the product furnished is unaffected by any considerable amount of deleterious minerals. The worst blemish arises from an occasional concentration of the feldspar individuals and occasionally disseminated bright pyrite crystals. The minerals, such as laumontite, stilbite, etc., for which the quarry is well known, do not occur within the body of the rock, but are secondary products distributed along the jointing planes. They accordingly are not injurious to its strength or weathering properties. Material has been furnished from these quarries for a good many well known buildings, especially in the city of Baltimore. Some material has also been shipped to Virginia. Perhaps the most prominent structures which have used this stone are the Traction Power House, a portion of the new Penitentiary and the Bolton Synagogue. In these buildings the stone is used chiefly as a foundation stone, the superstructure being constructed in part of Port Deposit granite and in part of other domestic stone. Besides furnishing first-class foundation material the quarries utilize their waste by means of crushers in the preparation of crushed stone suitable for the construction of roads and gravel walks.

The openings somewhat farther west, owned and operated by David Leonard, produce some of the best stone from this region. They were opened sometime prior to 1850 and have been worked more or less continuously ever since. The stone is very similar to that of the Edmondson Avenue quarry possessing the same marked bedding and several sets of joints, which allow the extraction of the stones in rectangular blocks of convenient size. It is probable that in this quarry the jointing is a little more irregular and the material furnished a little less satisfactory for the production of large blocks of foundation stone. This slight difference in the character of the material extracted has led the present owner to work a considerable portion of his stock into paving blocks. The distance of the haul and the sharp hill, which limits somewhat the load, increases a little the expense of furnishing the stone in the center of the city. The quality of the stone, however, which when cut is fully equal to that of any of the quarries about Baltimore, together with the uniform faithful-

ness in fulfilling contracts causes a steady demand for the product of the quarry.

In addition to these two quarries, there are others in the immediate vicinity, which are worked in a small way, furnishing a little material now and then for various local demands. These, however, change hands so frequently and are worked so irregularly that they do not seriously affect the market for stone of this general character.

Besides the larger quarries of the area just considered there are scattered in various directions about Baltimore, especially to the east and north of the city, several others which have been worked to some extent to supply the local demand for building stone. Such openings are worked occasionally along various portions of Herring Run, near Hall Spring, and Ivy, and along the upper course of Gwynn's Falls. near McDonogh. These quarries furnish material similar to that obtained from those on Jones' Falls and Gwynn's Falls and help to supply the demand for paving blocks, sills, steps and curbings in their local areas. The chief sale for this product, however, arises from its use as a road ballast in the construction of many of the pikes which radiate from Baltimore. The material is crushed and furnishes a very fair road metal.

GABBRO.

Although the gabbro or "niggerhead rock" of Harford, Baltimore, and Howard counties is sharply separated from the granites and gneisses scientifically, when used as a foundation and building stone it competes with the granites and gneisses, so that it is proper to consider this material under the general title of the present division. The stone is so hard to work and so sombre in its effect, that little or no demand has ever been developed for it. There are, however, a few buildings such as the railroad station at Arlington, a church and some of the mills at Woodberry and a few scattered structures in the valley of the Patapsco which have been made of it. The stone is generally used in natural boulders, as the drift materials of the New England states is used in the construction of higher grade of Queen Anne houses. The slight demand for dressed gabbro, the use of boulders and its plucky character have practically precluded the suc-

cessful exploiting of this rock for building-stone purposes. There is, however, a strong and ever increasing demand for materials of this character in the construction of macadamized roads, since as a road metal there is no substance in the state better adapted for this purpose.

AMPHIBOLE SCHIST.

Carroll county, about Westminster, and Montgomery county, northwest of Washington, possess a finely crinkled, compact rock which has been used in a few instances as a building stone with good effect. The material quite probably is a metamorphosed amygdaloid, in which most of the minerals have been changed to very stable forms. It is of a pleasing grayish green color and even texture, and when freshly furnished it is very easily worked, being carved in almost any form with ordinary tools. On exposure it hardens through a secondary deposit of silica, and becomes a very serviceable stone. It has been used in the Keyser Memorial Church at Reisterstown, in the residence of the president of the Western Maryland College, and in the foundations of many of the more prominent buildings in Westminster. Some of the stone, which was used as a base of the buildings constructed there at the beginning of the century, shows that it suffers little or no disintegration from exposure to the atmosphere. This material will never be used extensively as a building stone, since it is very uneven in its appearance and limited in its local occurrence. The porosity of its texture causes it to collect dirt rapidly and so it becomes unsightly if used in the large cities.

MARBLES AND LIMESTONES.

The marbles and limestones of Maryland are the most uniformly distributed of all the building stones in the state, for larger or smaller areas may be found in Baltimore, Carroll, Howard, Frederick, Montgomery, Washington, Allegany and Garrett counties. These differ widely however, in character, mode of occurrence and geological age. Unlike the granites, gneisses and serpentines, they are not confined to the central portion of the state, called the Piedmont Plateau, since they are found well developed in the broad Hagerstown and Frederick

valleys and in the more mountainous areas of the Alleghanies. The exposures are almost always poor on account of the relative readiness with which these rocks break down under atmospheric agencies, and from the same cause they always occur in valleys and never along ridges or the crests of mountains, as the sandstones do. Moreover, whenever there occur sufficient bodies the valleys are characteristically broad, flat and very fertile.

According to their geological age the marbles and limestones have undergone various degrees of change, since the time of their formation. There is a progressive increase in their crystalline character and freedom from fossils, from the little changed fossiliferous Greenbrier limestones of Garrett county to the crystalline, non-fossiliferous marbles of Baltimore county. This increased alteration, which they have undergone, is accompanied by a change in color from the dark limestones of the Carboniferous and Lewistown formations through the lighter Shenandoah limestones to the variegated marbles of the Phyllite formation and the clear white or blue marbles of unknown age which are so extensively worked in Baltimore county.

The geological formations which furnish either limestones or marbles are the

Triassic (Newark), running as a narrow belt across Montgomery, Frederick and Carroll counties;

Permian (Frostburg), occurring in a few hills about Frostburg;

Carboniferous (Bayard and Greenbrier), forming several bands of limestone in Garrett and Allegany counties;

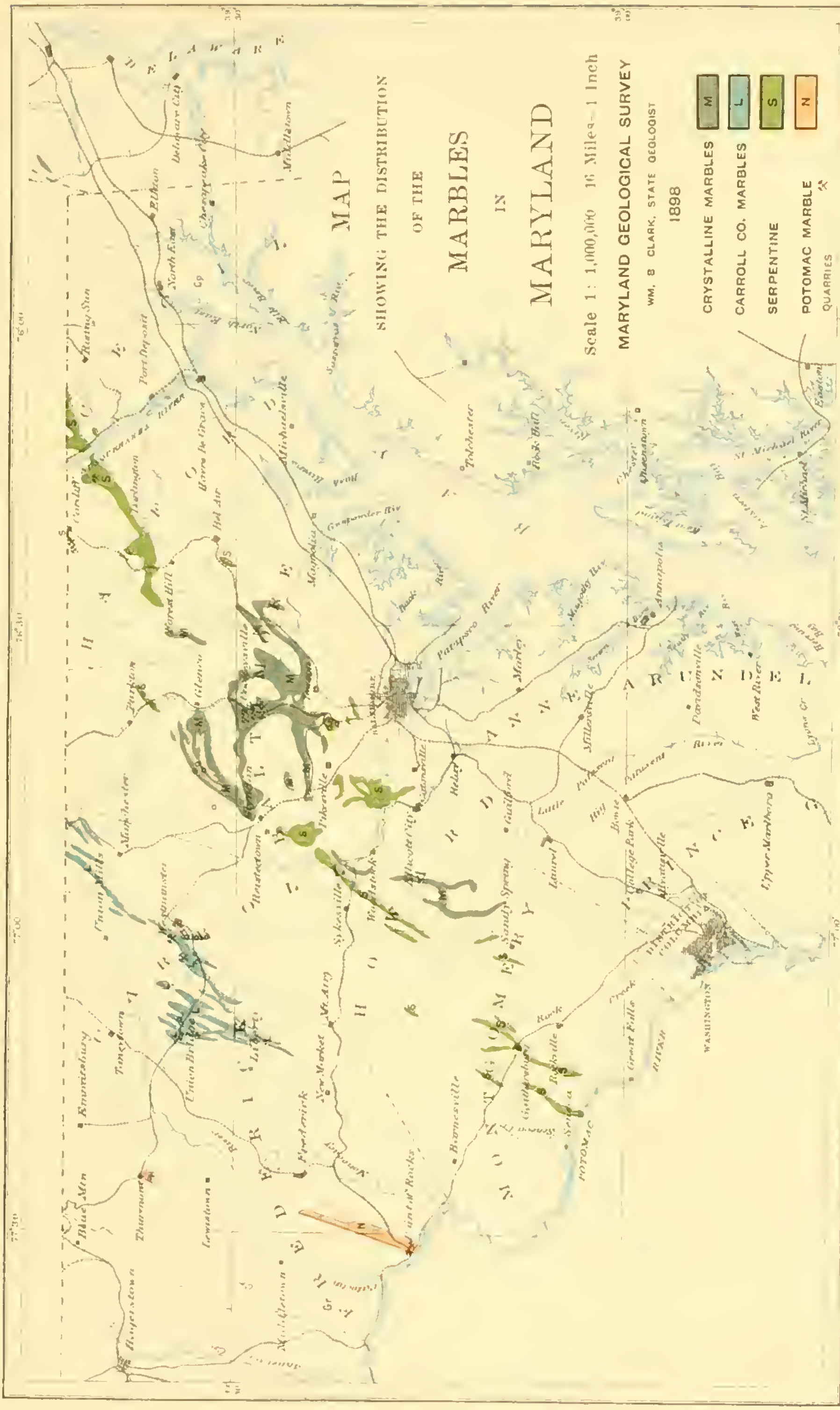
Silurian (Lewistown), with its heavy beds of limestone in several belts confined to the western and eastern portions of the Central Appalachian district, in Allegany and Washington counties;

Cambro-Silurian (Shenandoah), blue and gray limestones, dolomites and marbles, forming the broad and fertile Hagerstown and Frederick valleys in Washington and Frederick counties;

Undetermined, interlocated in the phyllites of Frederick and Carroll counties, and the

Archean (Algonkian ?) marbles of Baltimore and Howard counties.

According to their character, their occurrence and the uses to


MAP
SHOWING THE DISTRIBUTION
OF THE
MARBLES
IN
MARYLAND
Scale 1: 1,000,000 16 Miles = 1 Inch
MARYLAND GEOLOGICAL SURVEY
WM. B CLARK, STATE GEOLOGIST
1898
CRYSTALLINE MARBLES
CARROLL CO. MARBLES
SERPENTINE
POTOMAC MARBLE
QUARRIES
M
L
S
N
LITH BY A HOEN & CO BALTO

which these various stones are put they may be grouped for discussion in the following subdivisions:

The Marbles, including the highly crystalline dolomites and marbles of Baltimore, Howard and Carroll counties.

"*Potomac Marble*" or breccia which is found locally in the "Red beds" of the Newark Formation (Triassic) in Montgomery, Frederick and Carroll counties.

Serpentines or "Verde Antique," of Harford, Baltimore and Montgomery counties.

The Limestones, including the crystalline blue and gray limestones, magnesian limestones and "dolomites" of Frederick, Washington, Allegany and Garrett counties.

MARBLES.

The marbles of Maryland have been known for their excellent effect in building and monumental work since the beginning of the century. They are all confined to that portion of Maryland composed of the highly crystalline rocks of the Piedmont Plateau, while those of economic importance at the present time are confined to a small valley known as the Green Spring Valley extending east and west at a distance of 12 to 20 miles north of Baltimore.

This broad and beautiful valley sends off several large arms into the surrounding hills of gneiss and granite in such a way that the areal distribution is so anomalous and irregular as to render any explanation of the structure unsatisfactory. The same irregularity in distribution is noticeable in the marble areas between Glyndon and Glencoe and west of Ellicott City. This complexity of structure has led to various views regarding the age of these deposits. Ducatel[1] and Alexander from their study of the formation in 1833 regard them as "primitive." Tyson[2] in his first report classes them with the "metamorphic rocks" and evidently regards them as Silurian since they are placed on his map and in his list of "Geological Formations"[3] between the Chazy-Black River and Trenton. In the

[1] Report on the Projected Survey of the State of Maryland, Annapolis, 1834, p. 21.

[2] First Report of Philip T. Tyson, State Agricultural Chemist [1860], p. 30.

[3] Same, pp. 30, 35-36.

"Report on the Building Stones" of the Tenth Census Mr. Huntington[1] describes the area as "a small isolated area of Lower Silurian limestone bounded by rocks of Archean Age," and calls attention to the fact "that almost all of the marbles of commerce so extensively quarried east of the Alleghanies are from strata of Lower Silurian Age." Somewhat later Dr. G. H. Williams who made a detailed study of the area expressed the conclusion that[2] "The position to be assigned to this complex [gneiss, marble, quartz-schist] in the geological column is a matter deserving careful consideration, although data for a perfectly satisfactory conclusion are not at hand. It is believed that these rocks are demonstrably older than the altered lower Paleozoics of the western Piedmont region; and yet that they themselves contain in their chemical composition, stratigraphy and the presence of certain obscure conglomeratic beds near Washington, evidence of a clastic origin. For these reasons, as an expression of our present knowledge, the complex is provisionally assigned . . . to the Algonkian horizon." This view was subsequently restated[3] and held by the author until his death.

The marbles of this eastern area are throughout much coarser than the lenses of fine compact crystalline marble found intercalated in the phyllites of Carroll and Frederick counties. "Another striking contrast between the marbles of these two regions is, that, while the latter contain their impurities in the form of thin argillaceous bands, the former have theirs represented by layers of perfectly crystallized silicates." The western marbles also seem to be much more shattered and more difficult to work than the somewhat uniformly jointed marbles of the Cockeysville area.

Cockeysville and Texas.

These two towns are located on the Northern Central Railway about fifteen miles north of Baltimore, and are separated from each other by a distance of a mile and a half. Although situated so close together, and representing but parts of a single formation in a common

[1] Building Stones and the Quarry Industry. Tenth Census, p. 177.

[2] Guide to Baltimore, p. 89.

[3] Maryland, its Resources, Industries and Institutions, Baltimore, 1893.

valley, the quarries expose rocks showing many differences in composition, purity, coarseness of grain and texture, which have developed different industries in the two places. The rock at Texas is a coarse-grained marble of nearly pure carbonate of lime suitable for use as a flux or fertilizer, while that at Cockeysville is a finer-grained dolomitic marble, rich in magnesium and well adapted to building and decorative purposes.

It is not known when the stone of this area was first used or first recognized as of economic importance. The first recorded description is that in a letter by Dr. H. H. Hayden[1] to Dr. Nathaniel Potter in which he writes: "Immediately to the northward, as well as to the eastward of the Bare Hills the limestone commences. This, I believe, is its first appearance in the vicinity of Baltimore, which is distant six miles. From this to the distance of twenty miles to the northward, and how much farther I am unacquainted, the limestone tracts discover a variety of transitions. In many places it approaches so near to a marble, as to render it not only useful, but highly valuable in almost every branch of civil architecture; and the prospect is favorable to a supply of such as will answer every purpose of statuary and sculpture in all their variety."

That Dr. Hayden's view of the adaptability was correct was soon shown by Mr. Mills in the construction of the Washington Monument in Baltimore, the cornerstone of which was laid on the Fourth of July, 1815. A lack of funds delayed the completion of the monument for nearly fifteen years, and it was not until the 25th of November, 1829, that the last piece of the statue, comprising the bust, etc., was raised to the summit.

The three blocks constituting the figure of Washington were originally quarried as a single piece over seventeen feet long at the Taylor quarry, about a quarter of a mile west of the railroad at Cockeysville, and presented by F. T. D. Taylor of Baltimore county. The marble used in the monument, which came in part from the Taylor quarry and in part from the Scott quarries five miles farther north, was

[1] Hayden's Geological Sketch of Baltimore. Jour. Balto. Med. & Phil. Lyc. vol. i, 1811, pp. 255-271. Repub. Bruce's Amer. Min. Jour., vol. i, New York, 1814, pp. 243-248.

donated by General Charles Ridgely of Hampton, and the stone-cutting was performed by General William Steuart.[1]

After this increased demand for marble as a building stone, it is doubtful if much material was taken out for use in structural work during the succeeding fifteen years; the trade in lime for agricultural purposes, however, increased rapidly during the years following the war of 1812, until it was estimated that fully 200,000 bushels were produced annually. This trade was so extensive, that in 1839 there were fears expressed that the old quarries were nearly exhausted. The popular apprehensions became so great that the State Geologist, J. T. Ducatel, made an investigation which showed the practically inexhaustible character of the deposits. The same year (1839) Mr. Gilmore[2] offered to furnish stone to the Federal Government at 90 cents per cubic foot.

From this same report (1839) we gain the first information concerning the operators in this region in the statement that " the quarry on the lands of Mr. Wm. Bosley has been worked for many years past by Messrs. Baker and Connolly." The senior member of this firm was one of the first owners of this marble property and he did much to develop the industry. Sometime in the early forties Mr. Baker associated with him in the business his son-in-law James B. Connolly, who succeeded to the business on the death of Mr. Baker.

The fullest account we have of the early workings of the area is that given by Dr. David D. Owen[3] to the Building Committee of the Smithsonian Institution after his visit to the quarries in the early part of 1847. He found at the time some thirteen quarries in moderately active operation, the product being used for both building and agricultural purposes.

Five operators, Messrs. Samuel Worthington, Griscom and Burroughs, Fell and Robinson, E. J. Cooper and Thos. Symington, made bids for furnishing the stone for the Smithsonian Building without success The stone at that time was offered at $1.87 to $2.20 per

[1] Scharf's History of Baltimore City and County, Maryland, Phila., 1881, pp. 265-267.

[2] Ex. Sen. Doc., 25th Cong., vol. v. No. 221.

[3] Sen. Doc. 30th Cong., 1 Sess., No. 23, pp. 25-30.

perch of 3000 pounds for rubble delivered free on board the cars at Cockeysville.

Of the quarries inspected by Dr. Owen only a few are still (1898) in operation, most of them having become exhausted.

Scott's quarry, which is located about five miles north of Cockeysville, has not been worked during the last forty years, as the opening was abandoned as soon as the good stock was exhausted. It was from this quarry that part of the marble for the Washington monument was obtained.

An old quarry formerly on the property of Mrs. Chisilla Owings, about 200 yards from the present Beaver Dam quarries, was opened in 1840 and worked till 1873. It was then abandoned on account of the poor quality of the stone, and is now filled with water. This quarry was operated for a time by the Sherwood Marble Co.

The old quarry of Thos. Worthington from which the stone was obtained for the City Hall in Baltimore is situated about a mile west of the railroad at Cockeysville Station. It was opened some years prior to 1845 and was abandoned in 1873, when the white stone was exhausted. It is now the property of Mr. William Wight.

Samuel Worthington's old quarry is located about half a mile southwest of the one just mentioned, and is now owned by Mr. E. Gittings Merryman. It was abandoned in 1873 on account of the poor quality of the stone. While in operation the stone was quarried only when orders were received for it.

A quarry now owned by Mr. Lenwood Parks is situated about a quarter of a mile west of the last mentioned quarry. It was opened originally by Charlotte Owings and has not been operated since 1855. It was worked only according to orders and the good stone was soon exhausted.

Another old quarry about a quarter of a mile north of Cockeysville on the property of Mr. Geo. Jessups was formerly operated by a Mr. Cockey. It was shut down about 1879, since it was impossible to get out stone of sufficiently high grade to compete with the product of the other quarries.

From the foregoing it is seen that the present quarries, operated

by the Beaver Dam Marble Co., have surpassed and outlived the competing quarries by the greater abundance and higher quality of the marketable stone. This company owns and operates the old Baker and Connelly quarry, which on the death of the senior partner was operated by Mr. Jas. B. Connelly, who left it to his sons Messrs. J. B. and T. F. Connelly. It was during the years 1859-61 that the huge blocks, each 26 feet in length, were furnished for the 108 columns in the National Capitol. These quarries were finally purchased by the present Beaver Dam Marble Co., capitalized at $100,-000. It began operations in 1879 with Mr. Hugh Sisson as president. To-day this is the only large operator at Cockeysville and at the time of writing it is busy furnishing material for the new Court House in Baltimore. It has already commenced the shipment of 38 ton monoliths which are to be used as columns. (See Plate XXII, Fig. 1.)

There are more of the old quarries still active in Texas than in Cockeysville, although little or nothing is done in quarrying stone for building purposes.

The Fell and Robinson quarry which was opened early in the century is situated a short distance west of the railroad. It passed from the hands of the original owners to a Mr. Miller, and from him to Mr. V. T. Shipley, whose heirs are now operating it. All the stone quarried is burnt in a single kiln which uses about 10 tons of stone daily.

Griscom's old quarry is on the east side of the railroad about 400 yards from the preceding. It is owned and operated by Mr. Wm. P. Lindsay, who employs about 30 men. Work is carried on all the year round, six kilns burning each day a load of about fifteen tons of stone apiece.

Burroughs' quarry is on the west side of the track and is now owned and operated by Yellott and Kidd, who burn about ten tons of stone each day.

Mr. William C. Dittmann operates the following old quarries: Mrs. Chisella Owings', situated on the property of Miss M. B. Price about a mile northeast of Texas and half a mile east of the railroad;

Cooper's quarry on the same property immediately on the railroad; the old John C. Bosley quarry at Texas and the Parks quarry, once operated by the Ideal Lime Co. Ten kilns are kept going throughout the year, consuming in all about 120 tons a day. It was from the old Bosley quarry that the stone in the North Avenue viaduct at Baltimore was obtained.

The Texas Lime Co. has a quarry at Texas which produces about 10 tons of stone daily.

Mr. Frank Lee has a quarry on his property about half a mile northeast of Texas which is worked throughout the year, producing about 10 tons of stone each day. The entire product is burnt and sent to the Baltimore chrome works, where it is used as a flux.

The *texture* of the eastern marble varies widely. The rock from Texas is a very coarsely crystalline marble or "alum stone" in which the individual grains are sometimes $\frac{1}{2}$ or $\frac{3}{4}$ of an inch in diameter. The constituents are weak in themselves and they are weakly held together. The single grains show twinning striae parallel to the crystal $-\frac{1}{2}$ R that have been produced by a pressure, causing a gliding of the molecules over one another which has weakened the strength of the grain. Such a texture as is here shown renders the rock nearly worthless as a building stone where small blocks must be used and great weights sustained. This is emphasized by the determination of the crushing strength, which is very low. The grain of the Cockeysville or Beaver Dam rock is fine, the individuals seldom exceeding $\frac{1}{16}$ of an inch in diameter, the component particles forming a closely interlocking aggregate. This interlocking of the grains tends to produce a more compact and harder rock whose crushing strength is high (67,000 lbs.) and absorption ratio low (0.213%). This difference in closeness of grain is not strictly a geographical one, since fine-grained marbles, similar to those at Cockeysville, may be found at Texas. There is at the latter point, however, little evidence of the occurrence of rock which will combine such fineness and closeness of grain, freedom from mica and pyrite, and abundance as is shown in the rock worked by the Beaver Dam Company at Cockeysville.

The uniformity in color is more marked at Texas than at Cockeys-

ville, where there are frequent zones or horizontal bands of crystallized silicates, which represent old impurities and possibly the original bedding of the rock. These darker bands which are composed of copper-colored mica (phlogopite), colorless, radiating tremolite, pyrite and quartz, sometimes obstruct the working of the quarries when the stone required must be large and cannot be stood " on edge." In the smaller blocks these bands are avoided by " facing " parallel to them and setting the blocks perpendicular to their natural bedding. Uniformity in the size of the grains and in the texture, on the other hand, are more prominent at Cockeysville than at Texas. This uniformity in texture distributes the strain more evenly, making the position " on bed " and " on edge " less essential.[1]

The color of the marketable Cockeysville rock is clear white,[2] with now and then a few streaks or bands of pale blue which give to the rock face a faint gray color. In the poorer grades of stone which are sometimes shipped as far as Baltimore for use as door steps, sills, etc., there are occasional brown bands where the mica has been more abundantly developed. When polished and kept clean the rock is of a dazzling whiteness, often noticed by visitors walking through the residence portion of Baltimore. If the rock is laid in ashlar the little interstices between the grains soon gather dust, and the bright effect of the white rock is softened to a dove-colored gray. This same toning effect may be noticed in buildings, like the Peabody Institute, Baltimore, which have been built of smoothed stone, that has not been scraped or repolished. The Cockeysville stone is thought by some to stain easily, but this fault may be avoided by carefully selecting for first-class work those pieces which are free from the pyrite that sometimes is present in little pockets or stringers. Few instances,

[1] After examining a large number of buildings where this stone has been used as a trimming and set " on edge," the writer is inclined to believe that the texture is sufficiently massive and granular to warrant such a setting, where the weight and exposure are not exceptionally large. This view seems to be borne out by the various results of pressure tests to which the rock has been subjected.

[2] The accompanying illustration (Plate XXI) hardly does the stone full justice since it fails to give the clear white color that is so characteristic for the stone.

MARBLE.

COCKEYSVILLE, BALTIMORE COUNTY

in the buildings examined, have shown any indication of staining from inherent impurities.

The Texas and Cockeysville stones differ in their chemical composition as well as in their texture and color. Although before 1850 there was some dispute as to which of the two rocks was richer in magnesium the question is now clearly decided. According to Williams "the long series of analyses which are constantly being made of the Texas rock by the Maryland Steel Company, where it is used as a flux, show that it does not average over five per cent. of carbonate of magnesia; a number of analyses of the Beaver Dam product, on the other hand, give the average amount of this substance as high as forty per cent." [1]

Analyses of Marble.

	I.	II.	III.	IV.
Insol.	5.57	....	2.33	2.00
SiO_2	......	0.44	......	......
Al_2O_3, Fe_2O_3	.40	......	......	......
FeO	......	tr.	....	....
CaO	29.08	30.73	29.30	52.08
MgO	20.30	20.87	20.81	2.38
HO	......	1.22	0.08	......
CO_2	44.26	45.85	45.31	43.54
	99.61	100.33	99.38	100.00

	Specimen.	Analyst.	References.
I.	Cockeysville.	Schneider.	Bull., 148, p. 255.
II.	"	Whitfield.	" " p. 255.
	"	"	" 60, p. 159.
	"	"	Guide to Baltimore, p. 98.
III.	"	Higgins. (?)	(recalculated.)
IV.	Texas.	estimated average.	

The exact limits of the areal distribution of the marble and the dolomite have never been determined because of the lack of exposures and the high state of cultivation throughout the area underlain by the two rocks. It seems probable, from the data at hand that the distribution presents an intricate interweaving of the two types which may yield much information on the subject of dolomitization if the workings ever present sufficiently continuous exposures of the rock surface.

[1] Maryland, its Resources, Industries, and Institutions, p. 135.

The microscopical texture of the Cockeysville and Texas rocks differs but slightly from that presented to the unaided eye. The grains interlock in about the same way and the interstitial areas left between them seem very small. The two rocks differ from each other, when seen with polarized light, since sections of the Cockeysville rock show fewer vari-colored bands than that from Texas, due to the secondary twinning of the small individuals of the carbonate of lime which is more susceptible to twinning through pressure than the magnesian carbonate. The two minerals are intimately mixed in their distribution, and only occasionally show any marked variation in the size of the grains. Accessory minerals are present, but they show no differences in texture beyond those evident to the naked eye.

Few American building stones have been as thoroughly investigated with reference to their crushing strength as the marbles of Baltimore county. From the time that Mr. Robt. Mills became interested in the properties of the Baltimore marbles, which he used in the construction of the Washington monument in Baltimore, the engineers and architects charged with the construction of the Public Buildings in Washington have watched with interest the behavior of this stone in structures. The use of these marbles in public buildings has also led to extended experiments on the part of government officials. Prior to 1837 all of the important public buildings at Washington were constructed of Aquia Creek (Va.) sandstone, which was so treacherous and unsightly after exposure that as early as 1839 an inquiry was instituted by Congress as to the availability and cost of marble and granite. At this time Mr. Gilmore offered to furnish marble from the Baltimore county quarries at 90 cents a cubic foot, and Mr. Mills, the government architect, highly endorsed the rock.

The first published results of crushing strength tests on Maryland marbles were obtained before 1851, as stated in Professor W. R. Johnson's paper on American and Foreign Building Stones (pp. 6, 7),[1] by Mr. Robert Mills and Dr. Charles G. Page. These tests were made on two-inch cubes of coarse "alum stone" from Texas and

[1] Comparison of Experiments on American and Foreign Building Stones to determine their relative strength and durability; by Professor Walter R. Johnson, Amer. Jour. Sci., 2 ser., vol. xi, 1851, pp. 6-7.

showed considerable range in values. Similar tests were also made on two-inch cubes of fine grained marble from Symington's quarry (now abandoned), which show much greater uniformity. Other experiments on Maryland marbles were made by Mr. Dougherty, Superintendent of the Washington monument in Washington, which gave still other results. Prof. Johnson noted the wide discrepancies in the figures obtained from these different experiments on material from the same localities, and concluded that the variations must be explained either on one or the other of three suppositions: 1st, that the strength of the different specimens of the rock is thus variable, and that consequently no certain reliance can be placed on its powers of resistance; 2nd, that the experimenting or the machines with which the testings were conducted were faulty; or 3rd, that the resistance to crushing for a unit of area at the base, increases in some ratio with the number of units composing that area, that is, with the actual area of the base.[1] Johnson favored the third explanation, but the second seems to be as much in accord with later results. Since these early experiments were conducted, great advances have been made in the manner, uniformity and accuracy of the testings, so that results obtained now are not to be compared or averaged with those of earlier workers. The conditions under which the testings are carried on cause the results to vary within wide limits.

The experiments conducted in the preparation of the present report were made with the greatest care and under the same conditions. All of the specimens were two inch cubes, placed between two quarter-inch thick soft pine blocks in exactly the same position, and the testing machine was run at the same speed in each case. Almost all of the blocks were cut from the average stock of a well-known stone-yard. Some were crushed just as they were received from the stone cutter, while others were crushed after they had been submitted to absorption, freezing and thawing tests.

The results are as follows:

		Crack.	Break.
1.	Cockeysville marble, unoriented without immersion	.....	57,740
2.	" " " " "	......	81,580
3.	" " " after absorption and freezing.	......	60,240
4.	" " " " "	47,560	69,800

[1] Loc. cit., p. 17.

Somewhat higher figures have been obtained at other times, as is shown by the accompanying letter, but the conditions of the testing are not known.

[Hugh Sisson, Esq.,
Baltimore, Md.,
Sir:—] Washington, D. C. [ ]

The compressive strength of the six 2″ cubes of Beaver Dam Marble, which you furnished, was as follows:

No. 1.	84,000 lbs.	
2.	90,000	
3.	90,000	
4.	84,000	
5.	95,000	
6.	94,000	
	89,066	Average.

Strength per square inch, 22,416 lbs. The strength of the large crystal marble is about 12,600 lbs. per sq. inch. The 1″ cubes have not yet been crushed, but I feel satisfied the result will not show a greater strength per square inch than those obtained in crushing 2″ cubes.

Very respectfully,
Your Obt. Servt.,
Geo. W. Davies,
Capt. Assist. Engineer.

By direction of Col. Casey.

It is therefore clearly shown that the rock from the Beaver Dam quarries at Cockeysville, *as usually furnished*, can well sustain any weight which the exigencies of structures may demand.

Many crushing tests were made on the coarse-grained "alum stone" from Texas in earlier years and the results have been brought together by Johnson. The most satisfactory test, however, is furnished by the Washington National Monument itself, which shows the Texas rock (Griscom's lime quarries) subjected to increasing pressure from top to bottom as given in the following table from the report made by Col. Thomas L. Casey, Corps of Engineers, United States Army, engineer in charge of the construction of the monument, to W. W. Corcoran, Esq., chairman of the joint commission for the completion of this structure dated July 27, 1878.[1]

[1] Quoted in Tenth Census, vol. x, Report on Building Stones, p. 359.

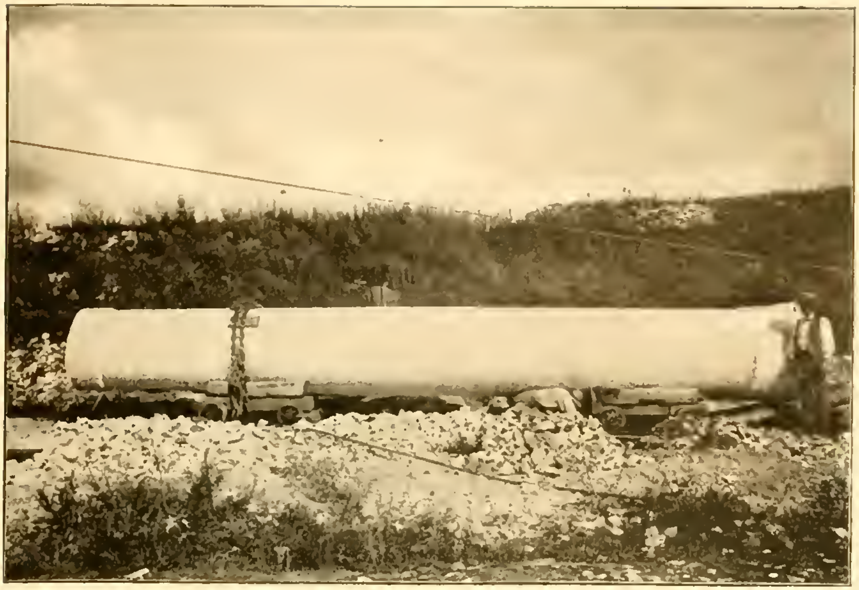


FIG. 1.—THIRTY-EIGHT TON MONOLITH, COCKEYSVILLE.

FIG. 2.—POTOMAC MARBLE QUARRY, POINT OF ROCKS.

Distance of joint from top, in feet.	Contents in cubic feet.	Average weight per cubic foot of masonry in several divisions.	Weight in pounds.	Pressure in tons (2240 lbs.) per square foot. Least.	Mean.	Greatest.	Distance of line of resistance from axis in feet.	Stability under action of the wind.
25	... ...		....	....	....	....	0.603	29.451
50	13,555		2,297,630	2.67	2.96	3.26	1.052	17.378
100	34,719	First Division, 169.5 pounds.	5,884,973	4.41	5.23	6.04	1.676	11.529
150	63,957		10,840,728	5.85	7.24	8.64	2.087	9.758
171.66	79,239		13,431,081	6.44	8.08	9.72	2.224	9.360
200	101,674		17,195,713	7.14	9.12	11.09	2.383	8.983
250	148,298	Second division, 167.8 pounds.	25,019,140	8.35	10.90	13.44	2.607	8.610
300	204,273		34,411,997	9.54	12.63	15.73	2.779	8.452
343.66	261,291		43,963,655	10.56	14.11	17.66	2.899	8.417
350	272,369		45,816,912	8.28	11.51	14.73	2.892	8.481
400	366,268	Third division, 165.8 pounds.	61,385,397	10.09	13.84	17.60	2.869	8.902
450	470,495		78,666,278	11.76	16.03	20.30	2.889	9.190
500	585,476		97,264,244	13.38	18.02	22.658	2.928	9.413

The fact that the coarse-grained marble without crushing actually withstands a pressure of 28,796 [1] pounds to the square inch when this pressure is applied evenly and slowly would seem to indicate that stone like that from Cockeysville might withstand under similar circumstances a pressure of fully twice as much as the figures given, since the earlier tests by Mills and by Dougherty place the strength of the "Symington" stone at twice that of the Texas rock.

The freezing tests which were conducted by Dr. Charles G. Page according to the Brard method described on page 104 gave the following results: [2]

[1] Computed on the assumption that the value of the crushing weight varies as the third power of the side of the areas compared.

[2] Report of the Board of Regents of the Smithsonian Institution. Sen. Doc. No. 23, 30th Congress, 1st Session, p. 21.

Spec. marked.	S. G.	Weight per cubic ft.	Loss by frost in grains.	Per-cent. of loss.
2. Symington's close-grained marble (similar to Worthington's.)	2.834	177.1	0.29	0.026
4. " large crystal marble,	2.857	178.5	0.50	0.069
5. " blue limestone,	2.613	163.3	0.34	
8. Port Deposit granite,	2.609	163.0	5.05	

Since the cubes used were but one inch in diameter they did not weigh over 720 grains and the percentage approximates the values given in the fourth column.

During the preparation of the present report Mr. Shellenberger tested the rock by depositing two-inch cubes in a freezing chamber for forty-eight hours and subsequently drying them at 212° F. The percentage loss from freezing and thawing, calculated on the difference between the original weights before immersion and after drying, was obtained as follows:

Mark on cube.	Kind of stone.	Weight after drying 24 hours at 212° F. Grams.	Weight before freezing 48 hours at 2° F. Grams.	Weight after freezing 48 hours at 2° F. and then dried at 212° F. for 24 hours. Grams.	Loss in weight. Grs.	Per cent of loss by freezing and thawing.
3.	Marble	367.15	367.93	367.13	0.02	0.005
4.	"	367.07	367.86	367.03	0.04	0.11

These figures and practical experiments show that a cubic foot of the Cockeysville rock weighs about 175 pounds per cubic foot or 4,375 pounds per perch of twenty-five cubic feet.[1] They also indicate that the close-grained marble (now the only one in general use for buildings) is exceptionally non-absorbent and resistant to the disintegrating effect of frost. This is well borne out by a study of the oldest structures standing, which show little or no "spalling" as the result of frost action, and the character of the weathering shown in the quarries.

The "dry seams" which have caused occasional loss, as in the case of the Baltimore Court House monoliths, seldom prove troublesome in the material furnished for ordinary buildings, since they may

[1] When sold by weight it has been customary to figure 3,000 lbs. to a perch.

usually be avoided in the smaller blocks. The strain which cause them to open after dressing is also more evenly distributed in structures using smaller pieces of stone.

The mineralogical and chemical composition of carefully selected blocks of marble from Cockeysville show that little more can be desired to assure the stability and consequent durability of the stone. When care is taken to avoid the few bands and pockets of pyrite and mica there is nothing in this rock which will render its decomposition rapid, as all the accidental or accessory constituents are in the form of stable compounds such as tremolite, tourmaline, or quartz. These in the first-class stock are seldom in any abundance, with occasional exception of finely fibrous and disseminated colorless tremolite. The outcrops, though decayed from ten to twenty feet below the surface, show the rock to be very durable for a carbonate, especially as the entire area of its occurrence has been exposed more or less continuously to disintegrating influences since at least late Tertiary time without any period of scouring by glaciers. Old tombstones, said to have been cut as early as 1829, show their lines as sharp and their surface as smooth as pieces which have been exposed to the atmosphere for only a few years. Little discoloration has developed beyond the darkening due to dust or nearby brick or iron.

The other areas of marble, similar to that of the Green Spring Valley, are not worked for building stone, but the whole product is burnt for lime, which is generally applied to the land of the immediately adjacent country. The centers of distribution are Butler in Baltimore county; Marriottsville and Highland in Howard county. Both Butler and Highland are so far from railroads and so lacking in transportation facilities, that they will never compete with the Cockeysville product so long as conditions remain as at present.

Marbles of Carroll County.

Intermediate between the clear white, fine grained saccharoidal marbles of Baltimore and Howard counties and the crystalline dark blue and gray limestones of the Hagerstown and Frederick valleys are the variegated marbles of Carroll county, which have furnished samples unsurpassed in beauty and variety by those of other states.

At the Centennial Exposition in Philadelphia in 1876 there were exhibited specimens of "deep red," "dark red veined with white," "salmon colored," "lavender veined," "undulate pink and white" and "ruby" marbles which came from Carroll and Frederick counties. Besides these many others might have been supplied. Some samples of the stone resemble the deeper colored Tennessee marbles, while others suggest the yellow Sienna, but lack its bright, clear tone.

All of these varieties occur in lenses in the phyllites which in certain localities have been shown by Mr. Keith to be of Cambrian age. The lenses do not occupy any considerable extent or present large exposures, but instead are confined to valleys which are long and narrow and are the direct result of the readier removal of the calcareous rocks than of the adjacent shales and sandstones. The marbles thus occupy the bottom lands and seldom outcrop high above the level of the streams. All of the valleys formed in this way trend parallel to the longer axes of the lenses in a N. E.-S. W. direction, as is well represented in the valley east of the road from New Windsor to Unionville and in the smaller valleys at the south of Spring Mills P. O.

Up to the present time the method of extracting the stone has been very crude, since the only desire has been to obtain the rock in pieces small enough for foundations and ordinary buildings. According to information furnished by Prof. Uhler, there has been a marked deterioration in the method of quarrying these marbles since he first began to study these rocks. Formerly considerable attention was paid to the extraction of the stone without explosives, while at the present almost all of the quarries use powder or dynamite to loosen the rock and render its extraction easy. During the earlier workings beautiful slabs were taken out for altar fronts and interior decorations. From a study of the walls of the small quarries it seems probable that no blocks can now be obtained in size, shape and quantity for first-class building purposes. The jointing is not trustworthy and the rock tends to break down into thick angular blocks varying in size from eight cubic feet to small fragments. Careful work with channelling-machines or diamond drills and a discontinuance of explosives might allow the quarrying of blocks which would be valuable for interior decoration in the form of mosaics and mantels.

Another serious drawback in working these rocks, which appear so beautiful in samples, is the irregular distribution of the colors, which seem to obey no rule and to follow no definite course. The white may be replaced by red or the red may be replaced by blue and so on. There seems, however, to be a greater amount of red and white or clear white than anything else. The variations in color are so frequent and uncertain, that it seems doubtful, if any quarry now opened could fulfill any moderately large order with material like a given sample. That there are beautiful marbles within these lenses is beyond doubt, but a suitable place for the development of a profitable industry in them has yet to be found.

Among the openings in these marbles in Carroll county, which are used quite generally for lime, are the following:

Jonas Bachman, Bachman's Mills; Wm. H. Eberhart, Bachman's Mills; Jeremiah Brown, New Windsor; Samuel Harris, Lessee, New Windsor; Eph. Stouffer, New Windsor; John T. Dutterer, Silver Run; Wm. A. Leppo, Silver Run; J. C. Robertson, Warfieldsburg P. O.; E. J. Gorsuch, Westminster; Wm. A. Roop, Westminster; Henry B. Rigle, Westminster.

At various points around the northern end of the Blue Ridge and occasionally along the course of the Shenandoah river Mr. Keith has found a local development of white marble, which is often pure white, with an exceptionally even grain, resembling a high grade statuary marble. Mention of such material may be found in the reports of the earlier state geologists, and the exposures have been met with in several places, but in no instance have they been free from stain or jointing in masses which offer a reasonable return for investment. Such, however, may sometime be found, although Keith considers that this marble is not of sufficient body to be valuable. Small quarries have been opened near Keedysville and just below the station at Edgemont, but these have not been adequately developed.

POTOMAC MARBLE.

The most interesting building material in the entire state of Maryland is the "Potomac marble," "calico rock" or "Potomac breccia," which has been used occasionally for the greater portion of the cen-

tury. The chief interest in this rock arises from the fact that it is "the only true conglomerate or breccia marble that has ever been utilized to any extent in the United States."[1]

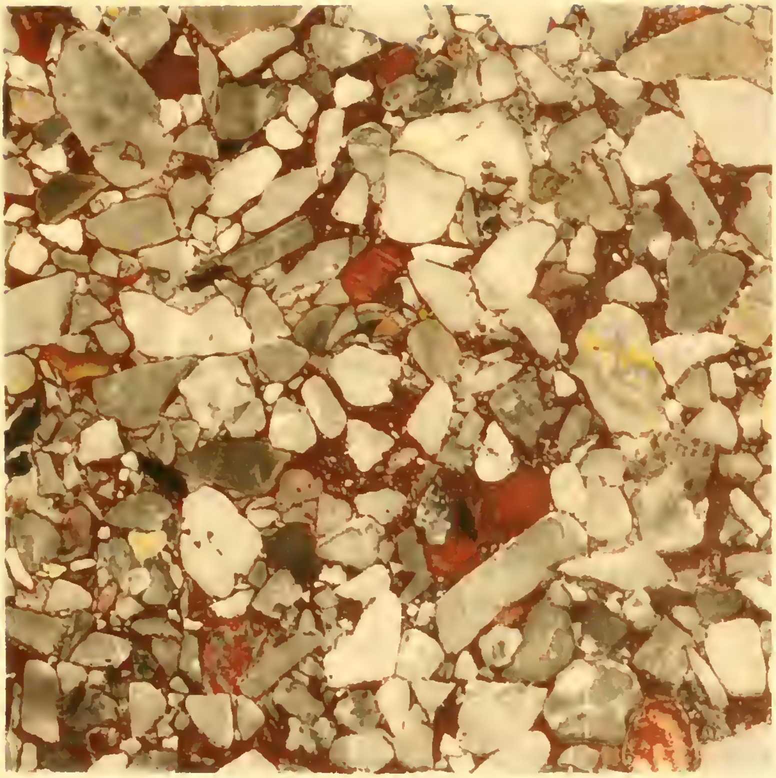
This conglomerate is found in several places along the eastern slope of the Blue Ridge and is most extensively quarried in the vicinity of Point of Rocks, Frederick county near Washington Junction on the Baltimore and Ohio Railroad. The quarries are small affairs, which have been operated spasmodically. The one in operation at the present time is located about a mile east of the Washington Junction station on a spur which runs northeasterly from the Metropolitan Branch.

This rock was first brought into notice by Mr. B. H. Latrobe, Superintending Architect in the construction and repair of the Capitol and White House before and after the war of 1812. In his report on the public buildings, read February 14, 1817,[2] Mr. Latrobe gives the first account of the use of this marble as a building stone, as follows: "For the columns, and for various other parts of the House of Representatives, no free-stone that could be at all admitted has been discovered. Other resources, therefore, were sought after. A stone hitherto considered only as an encumberance to agriculture, which exists in inexhaustible quantity at the foot of the most southeasterly range of our Atlantic mountains—probably along the greatest part of their extent, but certainly from the Roanoke to the Schuylkill, and which the present surveyor of the capitol, and probably others, had many years ago discovered to be a very hard, but beautiful marble—this stone was examined, and, after much labor and perseverance, has been proved to answer every expectation that was formed, not only of its beauty, but of its capacity to furnish columns of any length, and to be applicable to every purpose to which colored marble can be applied.

"The present commissioner of public buildings has, therefore, entered into a contract for all the columns, and progress has been made in quarrying them. They may be procured each in a single block should the transportation be found convenient.

[1] Merrill. "Stones for Building and Decoration," New York, John Wiley and Sons, 1891, p. 92.

[2] Senate Documents, 14th Congress, 2nd Session, No. 101, pp. 3 and 6.



POTOMAC MARBLE.

POINT OF ROCKS, FREDERICK COUNTY

"A block of one of the pilasters lies ready to be brought down to Washington, and will, probably, arrive in a few days. The quarries are situated in Loudoun county, Virginia, and Montgomery county, Maryland."

The columns which were then procured are still standing in the old House of Representatives, now used for the sittings of the Supreme Court. The quarries whence they were obtained have never been fully developed, although Mr. Latrobe thought that he had found in the newly discovered marble of the Potomac an inexhaustible resource of the most beautiful building materials situated easily accessible by water. There is some doubt as to the exact location of the particular source of these blocks used in the capitol, although they were monoliths of considerable size for the time and the primitive means of transportation.

Plate XXII, Fig. 2, represents the opening reported to be the source. It is situated in the woods north of the Metropolitan Branch of the Baltimore and Ohio Railroad about half way from Washington Junction to the quarries now in active operation.

A few years later in his paper on the geology of the Southern States the Rev. Elias Cornelius[1] gives the following account of this brecciated limestone:

"It is also in the valley of this river [Potomac], and not far from its famous passage through the Blue Ridge, that immense quarries of beautiful breccia have been opened. This rock was first brought into use by Mr. Latrobe, for some years employed by the government as principal architect. It is composed of pebbles, and fragments of siliceous and calcareous stones of almost every size, from a grain, to several inches in diameter, strongly and perfectly cemented. Some are angular, others rounded. Their colors are very various, and often bright. Red, white, brown, gray, and green, are alternately conspicuous with every intermediate shade. Owing to the silicious stones which are frequently imbedded through the mass, it is wrought with

[1] On the Geology, Mineralogy, Scenery, and Curiosities of Parts of Virginia, Tennessee, and the Alabama and Mississippi Territories, &c., with Miscellaneous Remarks, in a letter to the Editor, vol. i, Amer. Jour. Sci., New Haven, 1819, p. 216.

much difficulty; but when finished, shows a fine polish, and is unquestionably one of the most beautifully variegated marbles, that ever ornamented any place. It would be difficult to conceive of anything more grand than the Hall of the Representatives, in the Capitol, supported as it is by twenty or thirty pillars formed of the solid rock, and placed in an amphitheatrical range; each pillar about three feet in diameter, and twenty in height. Some idea of the labor which is employed in working the marble may be formed from the fact, that the expense of each pillar is estimated at five thousand dollars. The specimens in your possession, are good examples of its general structure, but convey no adequate idea of its beauty."

The words of commendation and the beauty of the columns of the Capitol led the regents of the Smithsonian Institution to investigate the locality and to consider the availability of this rock for the building of the Smithsonian Institution. Accordingly in the spring of 1847 Dr. David Dale Owen visited these quarries which, on the whole, he found were worthless for the purpose in hand.

At the present time the work in the Potomac marbles is carried on almost exclusively by the Washington Junction Stone Co., which quarries both sandstone and Potomac marble. The former is obtained in good sized blocks but the latter is wrought almost entirely in small slabs. The marble is taken from a small opening about half a mile southwest of the quarry buildings. The conglomerates under discussion belong in the Newark formation, which extends along the western border of the Piedmont Plateau from Connecticut and New York southward. The development of the Potomac marble within the Newark is not great and there are but few exposures within the state. It is sparingly developed north of Frederick, a mile south of Thurmont and only barely represented at Point of Rocks on the eastern slopes of the Catoctin Mountain. According to Mr. Keith[1] this limestone conglomerate occurs in lenses or wedges in the sandstone ranging from 1 foot to 500 feet in thickness, or possibly even greater. They disappear through complete replacement by sandstone at the same horizon. The wedge may thin out to a feather edge or may be bodily

[1] Keith, Geology of the Catoctin Belt, 14th Ann. Rept. U. S. Geol. Surv., Washington, 1894, part ii, p. 346.

replaced upon its strike by sandstone; one method is perhaps as common as the other.

The conglomerate is made up of pebbles of limestone of varying size which sometimes reach a foot in diameter, although usually averaging about two or three inches. The fragments, which are both well rounded and angular, range in color from gray to blue and dark blue, and occasionally pebbles of quartz, chloritic schists and white crystalline marble occur. All are embedded in a red calcareous matrix mixed with a greater or less amount of sand. The pebbles are very similar to the magnesian limestones of the Shenandoah formation, developed in the Frederick and Hagerstown valleys and to the rocks of the complex which forms the Catoctin Mountain. Occasionally pebbles show evidences of having been decayed even before they became a part of the conglomeritic mass, but this may be due to their greater solubility, since the matrix does not show a corresponding degree of decomposition.

The bedding so far as it has been observed is irregular and of little importance in the quarrying of the rock, the lenticular character of the beds having far more importance than the position of the individual pebbles within the mass. In the same way the jointing is also a relatively subordinate feature since the different degrees of cohesion between the parts of the pebbles and that between the pebbles and the matrix play an important part in determining along what planes a rupture will take place. The texture shows a wide variation in the size of the grains, in the character of the material composing them, and in the relative amount of matrix between the grains and pebbles. This wide range in the size of the particles and in their abundance leads to many difficulties in polishing the rocks, but the difference between the hardness of the limestone and that of the quartz pebbles is particularly a source of expense and annoyance, since the hard quartz pebbles break away from the softer parts in which they lie, leaving numerous cavities to be filled with colored wax or shellac. This difference in the hardness and material of the pebbles, together with the conglomeritic character of the mass excludes the use of hammers and chisels. Any satisfactory quarrying of the blocks must be done with

saw and abrasive materials. It is this difficulty in the working, together with the fragile nature of the stone itself, which has kept it from the conspicuous place in the market, which its oddity and beauty deserve.

The chemical composition of breccia can scarcely be determined from a single analysis, and the figures obtained from an average of several analyses may be of little account. The values obtained depend very largely on the accuracy of the analyst, the fineness of the grain, the homogeneity of the specimens and the number of samples taken to make an average test. Higgins[1] gives the following as "the average of various analyses made of the Breccia marble, or Calico limestone, found in Montgomery, from which the pillars in the House of Representatives at Washington are made:"

Sand	12.25 per cent.
Iron and clay	1.00
Lime, as carbonate	70.50
Magnesia	15.00
Other constituents not worthy of estimation	0.25
Total	99.00

This is probably of little value in itself and should have no weight in estimating the value of the marble. The stone is particularly suited to mosaic work and interior decorations, and should not attempt any competition as a structural material with the stones now in common use.

The influence of microscopic structures in a stone like this breccia is more than over-balanced by the variations in the larger structural features of the rock. If the microscope or hand lens shows that the stone is sufficiently fine and homogeneous to take a good polish with few minute irregularities on the surface that is sufficient, still experience clearly shows that this rock will take a good polish and that it will withstand any pressure to which it may be subjected as an ornamental or decorative stone.

This unique material deserves to be fully exploited and pushed as a novelty in the highest class of interior furnishings. It is believed that a demand might be created for this stone in some of the best

[1] Second Rept. Jas. Higgins, State Agr. Chemist, Annapolis, 1852, p. 39.

FIG. 1.—WHITEFORD QUARRY, CAMBRIA, HARFORD COUNTY.

FIG. 2.—SLATE QUARRY, IJAMSVILLE, FREDERICK COUNTY.

work which is done in New York, Philadelphia, Washington and other large cities, where there is a call for materials which are suitable for floors and other interior decorations, striking in color and texture and of pleasing contrasts.

SERPENTINE.

Serpentine or "Verde Antique" has been quarried in Maryland for many years, but the annual production has always remained small. As this rock enters into competition with some of the marble for interior decoration it has frequently been classed as a marble, although so far as the Maryland deposits are concerned it is in no wise related to the marble, however intimately interwoven with calcite veins it may be. The deposits of the state are found in Cecil, Harford, Baltimore, Howard and Montgomery counties, where they have been worked to a greater or less extent in the hope of obtaining good material for general building or interior decoration. The most thoroughly exploited are those about Baltimore, at the Bare Hills, those on the banks of Broad Creek in the eastern part of Harford county, and a small area near Cambria in the northern part of the same county. That the stone is capable of furnishing beautiful slabs for decorative purposes is readily seen from the accompanying illustration (Plate XXV). The deposits on Broad Creek are situated in the midst of a large serpentine area, which extends from the Susquehanna southwesterly into Baltimore county. The nearest town is the small village of Dublin some three miles to the south, which is lacking in both railroad and canal communication. In the shipping of orders it is necessary to have all of the stone hauled to Conowingo on the Perryville and Columbia Railroad, a distance of three or four miles.

It is not known when the quarries on Broad Creek were first opened. Local tradition asserts that they were operated some years before the civil war. It at least seems probable that they were opened as early as 1870, since at the time Professor Genth made his report (1875), some of the shafts had been worked to a depth of 57 feet. The area was still earlier the scene of mining operations for iron, and it probably was prospected for chrome deposits about the beginning of the century. In 1875 the Havre Iron Co. of Wilmington, Delaware, asked Professor F. A. Genth of the University of Pennsylvania to

visit the area for the purpose of "examining into the nature and extent of the deposit of Green Ornamental Stone" occurring on their property. The results of this visit were published in a small pamphlet entitled "The Geological Report of the Maryland Verde Antique Marble."[1] How long this company operated for serpentine could not be ascertained, but evidently the quarries were not worked in the period just prior to 1880, when the Serpentine Marble Co. began operations in this district. This company operated the quarries in a more business-like way, constructing sawing sheds and polishing tables as well as a short railroad across Broad Creek on which they removed the refuse. The quarries when visited by the writer were not in operation on account of the lack of success, extravagant management and litigation arising from the death of the mortgagee, who held a mortgage on the property for $40,000. During the activity of this latter company considerable material was furnished for building purposes and for interior decoration, the principal market being New York, where the material was used entirely for decoration. The largest building constructed of this material is the Protestant Episcopal Grace Memorial Church of Darlington, Md.

The geological occurrence and the mineralogical character are similar to those of the serpentine deposits all along the eastern border of the continent, which occur as alteration products of basic magnesian rocks like peridotite. The changes which have taken place show all of the features of serpentinization with the development of accessory deposits of calcite, quartz, opal, gibbsite, deweylite, etc. The rock face of the quarries rises quite sharply from the bed of Broad Creek and offers every facility for operating above water level, and for the handling of the stone at little expense. There does not appear to be any marked bedding in the rock, although Genth seems to have regarded the mass as possibly of sedimentary origin. The ledge which has been worked seems to form a lens of more massive rock between more micaceous and schistose layers, the long direction of the layers having a strike of N. 69° E. The seaming of the rock is its least

[1] The Geological Report of the Maryland Verde Antique Marble and other Minerals on the lands of the Havre Iron Co. in Harford County, Maryland, by Prof. F. A. Genth, University of Pennsylvania, 1875, 9 pp., map.

favorable feature, since the seams run irregularly both in direction and and in distance, causing the stone to break up into irregular masses, which require considerable handling before they can be reduced to good form. The rock also gives evidence of having undergone considerable disturbance, as shown by the bands of fibrous serpentine which are often faulted to the distance of ½ or ¾ of an inch (Plate XXV). This seaming and faulting cause considerable waste and render the stone tender, so that it must be shipped with care and used where it is not subject to great pressure.

The texture of the stone does not vary very widely, and the impression is left that the stone works readily. If due care is used to avoid the use of explosives and the working of the stone after it has lost the so-called quarry water much of the waste may be avoided. The use of diamond drills or channelling machines offers the only method which will justify the expectation of profitable work. The stone as described by Genth[1] "is a variety of massive serpentine, somewhat resembling williamsite, and shows sometimes a slightly slaty structure. It occurs in various shades of green, from a pale leek-green to a deep blackish-green, and from a small admixture of magnetic iron, more or less clouded; rarely with thin veins of dolomite passing through the mass. It is translucent to semi-transparent; it is exceedingly tough, and its hardness is considerably greater than that of marble, scratching the latter with great ease."

The analyses of the deep green translucent and black mottled varieties gave the following results:

Silicic acid	40.06	40.39
Alumina	1.37	1.01
Chromic oxide	0.20	trace.
Niccolous oxide	0.71	0.23
Ferrous "	3.43	0.97
Manganous "	0.09	trace.
Magnesia	39.02	38.32
Water	12.10	12.86
Magnetic iron	3.02	6.22
	100.00	100.00
Hardness	4.00	4.00
Specific gravity	2.668	2.669

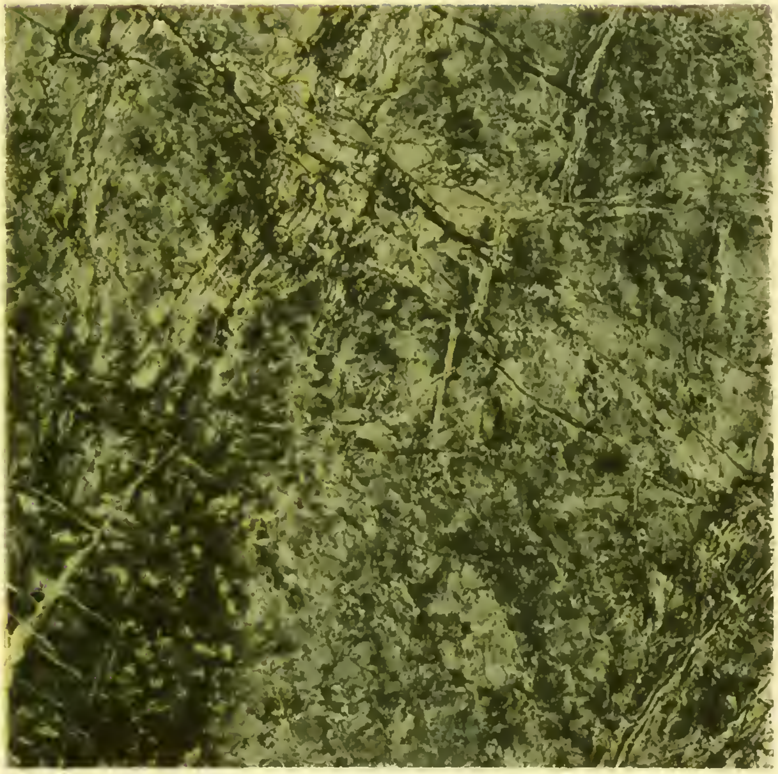
[1] Loc. cit. p. 7.

Merrill states in his "Stones for Building and Decoration" that the "specific gravity is 2.668, which denotes a weight of 166¾ pounds per cubic foot, or practically the same as granite. Specimens of this stone received at the National Museum admitted of a very high lustrous polish, the colors being quite uniformly green, slightly mottled with lighter and darker shades. It is not a true verde antique in the sense in which this name was originally employed. So far as can be judged from appearances, this is a most excellent stone, and admirably suited for interior decorative work."

Since the rock has been formed under conditions not far different from those existing at the surface, it is probable that no considerable degree of chemical decomposition will take place; the source of danger, however, lies in the tendency toward physical disintegration, brought about by pressure and frost action. The beauty of the rock, when polished, fits it pre-eminently for service as an ornamental stone, and, when used in the interior for ornamental veneering, the rock is not subjected either to harsh atmospheric action or to any detrimental amount of pressure.

What has been said of the Broad Creek quarries may equally well be said of the smaller opening operated by W. Scott Whiteford about three quarters of a mile southwest of Cambria, a small station on the Baltimore and Lehigh Railroad not far from Cardiff. This is the only quarry which has made any shipments during the last year. The opening whence the material is obtained is now filled with water and does not appear at first sight very favorable. As represented in the accompanying figure (Plate XXIV, Fig. 1), it is still small and there is considerable opportunity for expansion. The transportation facilities are good and the supply of material is sufficient to permit successful competition with other serpentine areas.

The rock worked seems more suitable than in many of the abandoned openings of serpentine, since it is firmer and somewhat more schistose. If the sawing is done parallel to the schistosity the expense is less and the slabs are relatively stronger. Cutting in this direction does not give quite as pleasing a texture to the surface, but the general effect is good. The stone from the Whiteford quarry is



SERPENTINE.

BROAD CREEK, HARFORD COUNTY

lighter and more mottled than that from Broad Creek. In its mottling it resembles the product from abandoned openings near White Hall, Baltimore county.

The plant includes machinery for sawing, grinding and polishing the rock by steam power and the operators have shown that in spite of the difficulties to be overcome beautiful slabs of polished stock 8′ x 4′ x 2″ may be obtained.

LIMESTONES.

The blue and gray limestones of Paleozoic age have never been quarried in Maryland as building stones except for local use. The most important and in fact the only one which has been used in prominent buildings is that from the Shenandoah formation of the Hagerstown and Frederick valleys. According to the Report of the 10th Census this rock is a magnesian limestone containing alumina and graphite, while earlier analyses made by Dr. James Higgins[1] show a wide range in the composition of specimens from different portions of the Hagerstown valley.

Analyses of Limestone.

SiO_2	5.80	0.25	2.40	3.00	0.70	2.00	0.60	6.00	0.20	2.00
Al_2O_3 Fe_2O_3	0.10	......	0.60	0.27	.....	0.64	0.00	.20	0.10	0.30
CaO*	50.79	56.18	53.07	30.21	30.76	31.64	55.18	50.79	54.32	53.20
MgO*	1.57	1.31	1.07	20.37	21.12	14.69	0.41	1.43	1.19	1.24
CO_2	41.58	44.01	42.87	46.06	47.40	41.03	43.81	41.48	43.99	43.16
Undt.	0.12	.25	tr.	tr.	tr.	0.00	0.00	0.00	0.30	0.10

* Computed from $CaCO_3$ and $MgCO_3$.

The quarries, according to Prof. Chas. E. Monroe, are on a belt locally called Cedar stone, a few hundred feet in width extending for a distance of several miles, and believed to be peculiar in the fact that the upper layers furnish the most desirable stone.

This stone is of a deep blue color when freshly quarried, but upon exposure there is slowly formed a thin white coating over the face of the rock, which brightens the color to a dove-gray, thereby greatly improving the appearance of the buildings. This change goes on uniformly and accordingly does not pass through the unsightly mottled stage.

[1] 3rd Report, p. 135.

There is no doubt that this rock might become of considerable importance economically as a building stone. At present, however, the residual soil, with which it is covered, lends itself so readily to brick making that there is little demand for stone except in heavy structures or for foundations.

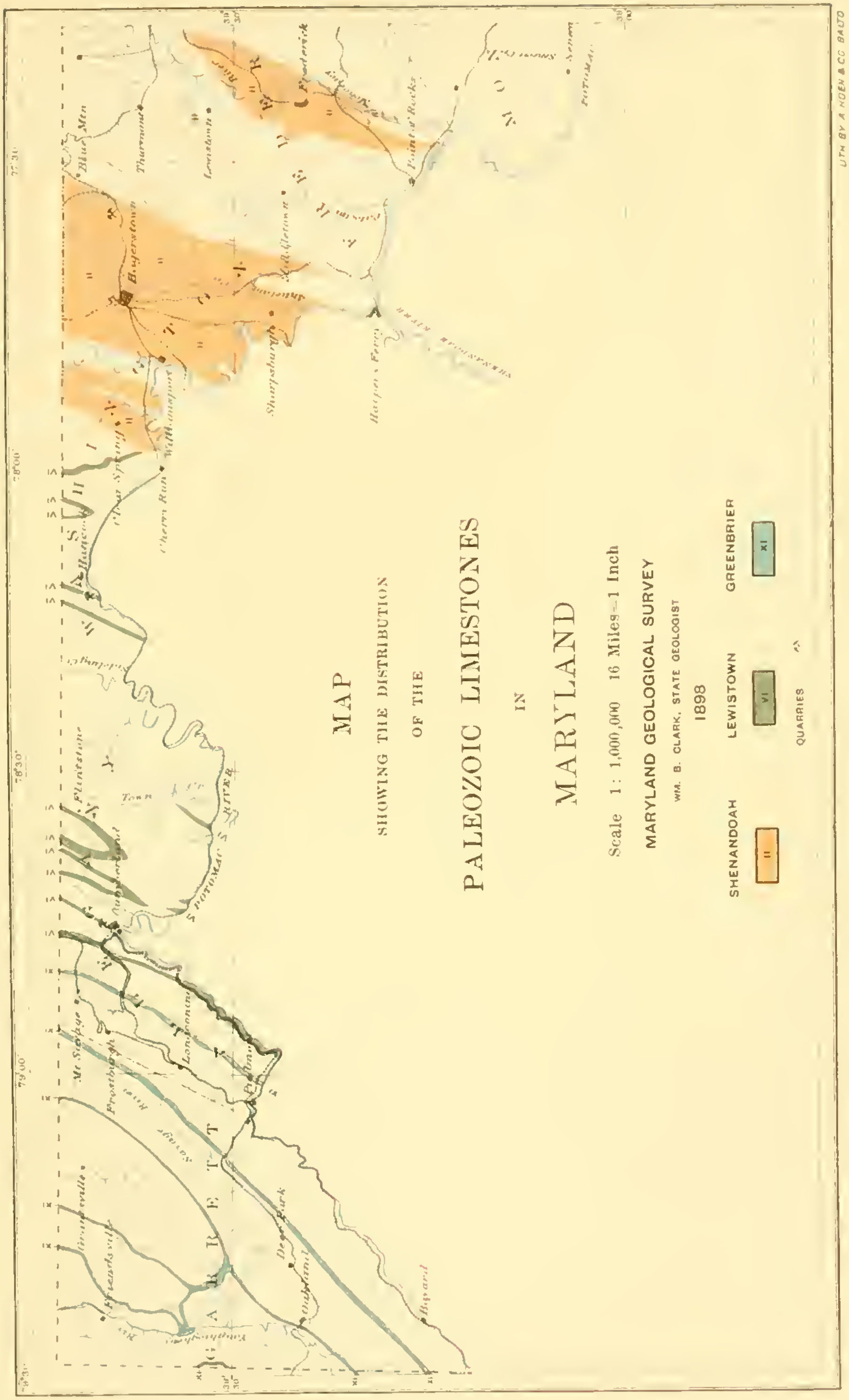
Many other areas in the Hagerstown valley offer limestones which may ultimately prove of importance as building stones. Openings in the rock are made only for lime at the present time, and the methods of quarrying, which shatter the rock by heavy charges, make the exposures look less favorable for the production of building stone than is actually the case. If proper care in extraction were exercised, there is no doubt but that large blocks of limestone could be quarried in many places throughout the entire valley, which would in some instances work into a good grade of "black marble."

In the Frederick valley little has ever been done towards quarrying the blue limestone for building purposes, as almost all of the stone which has been taken out has been burned for lime which finds a ready market. The buildings in Frederick show that there has been some quarrying for building material, since several of them are built of limestone and almost all of them have limestone foundations or sills.

West of the Hagerstown valley in Washington, Allegany and Garrett counties there are three Paleozoic limestones, namely the Lewistown, Rockwood and Greenbrier. Of these the first is the only one which offers reasonable grounds for expecting good building material within its limits. The upper massive beds of the Lewistown which outcrop in five or six small bodies along the Potomac from Hancock to Cumberland, and form a continuous belt from the latter point to Keyser, West Virginia, afford every indication that satisfactory building material may be obtained. Little if any work has been done in this formation because there have been no local demands.[1]

Of the two remaining formations the Rockwood is of such a nature that it cannot be used at all, and the Greenbrier is scarcely any better adapted to building purposes. Both formations occur in valleys with

[1] It is a matter of interest in this connection to note that outside of Cumberland and Frostburg there is scarcely a stone building in either Allegany or Garrett counties.


MAP
SHOWING THE DISTRIBUTION
OF THE
PALEOZOIC LIMESTONES
IN
MARYLAND
Scale 1 : 1,000,000 16 Miles=1 Inch
MARYLAND GEOLOGICAL SURVEY
WM. B. CLARK, STATE GEOLOGIST
1898
SHENANDOAH
LEWISTOWN
GREENBRIER
QUARRIES
Hagerstown
Frederick
Williamsport
Cumberland
Frostburg
Sharpsburg
Harpers Ferry
Point of Rocks
Flintstone
Deer Park
Oakland
Bayard
Thurmont
Blue Mtn
Clear Spring
Cherry Run
POTOMAC RIVER
LITH BY A HOEN & CO BALTO

very few outcrops. The latter division has a single exposure on the Potomac between Keyser and Piedmont, West Virginia, and is imperfectly shown on Jennings Run and Braddock's Run. It is also injured for structural purposes by the pyrite which occurs scattered through it.

Sandstones.

Although there is but one sandstone within the state which has attained any considerable reputation as a building stone, there are many formations in different parts of the area which furnish suitable sandstones for local construction. As is the case with all building stones the factor of transportation facilities is so important that only those deposits can come into general use which are situated adjacent to prominent lines of travel either by railroad or boat. The sandstones of the state range in geological age from those which are supposed to be Archean to those which belong to the Triassic period. According to their age and importance they may be considered under the following heads: the *Triassic sandstones*, the *Paleozoic sandstones* of the Pocono, Monterey and Tuscarora formations, the *Cambrian* or *Mountain sandstones*, and the *Micaceous sandstones* of the eastern Piedmont area. Their distribution is shown on Plate XXX.

THE TRIASSIC SANDSTONES.

The Triassic or "Seneca Red" sandstones are the only ones quarried in Maryland which possess a recognized reputation in the market, or which furnish materials for more than local work. The formation in which they occur is extensively developed along the eastern edge of the United States from Connecticut southward through New York, New Jersey, Pennsylvania, and Virginia, and in scattered areas into North and South Carolina. It is from rocks of the same age that the well-known building stones from Portland, Connecticut; Prallsville, New Jersey, and Hummelstown, Pennsylvania, are quarried. This formation enters Maryland from the north near Emmitsburg, and continues with varying width through Carroll, Frederick and Montgomery counties to the Potomac river. Between these limits there is an almost continuous belt locally known as the "red lands,"

which is divided into two areas by a small exposure of the underlying Shenandoah limestone a few miles west of Frederick, where the whole of the Triassic has been removed by stream erosion.

In either direction from this point the formation widens to about 16 miles at the Mason and Dixon line and 4 miles where it crosses the Potomac. East of this belt in the southwestern corner of Montgomery county there is also a broad area of the same formation which is continued southward into Virginia. It is to this southern area that the quarrying of sandstone is almost entirely confined. The prominent quarries are situated near the mouth of Seneca Creek, Montgomery county, on the Chesapeake and Ohio Canal about 23-25 miles northwest of Washington.

Seneca Creek.

The first use of this stone is not known, although it is evident that blocks of this material were utilized in the construction of the old Potomac canal built around the Great Falls of the Potomac in the year 1774. From that time until the present these quarries have been worked more or less systematically to supply the demands for local buildings and for shipment. During the extension of the Chesapeake and Ohio Canal from 1827 to 1833 considerable material was quarried for the construction of aqueducts and embankments, which is still in a state of good preservation. About this time, or soon after, some of the quarries of this area came into the possession of Mr. John P. C. Peter of Montevideo, near Darneystown, Montgomery county, Maryland, who was the owner of the quarries at the time when the stone was obtained for the Smithsonian Institution in 1847. Before the rock for the above building was quarried the area about Seneca Creek was visited and the quarries then opened were carefully examined by Dr. David D. Owen.[1] Somewhat later, after the stone had been adopted and the quarries practically selected, James Renwick, Jr.,[2] architect for the Institution, visited the quarries with a view of ascertaining their capability of affording a sufficient quantity of build-

[1] Report of Board of Regents Smithsonian Institution, Jan. 6, 1848, Sen. Doc. 30th Congress, 1st Session, No. 23, pp. 36-39.

[2] Same pp. 105-107.

ing material of uniformly good quality and color. From the reports of these gentlemen we learn that at that date there were several quarries which had been opened and worked usually on a royalty of 25 cents per perch for all stone quarried.

The quarry most extensively operated at that time was the so-called "College quarry," which lay about a quarter of a mile farther west than the quarries owned by Mr. Peter on Bull Run, from which the stone for the Smithsonian was obtained. Messrs. Peter, Lee and Vincent seem to have been the most prominent operators in the area. In 1867 Mr. Peter sold his quarry to Mr. H. H. Dodge, who organized the original Potomac Red Sandstone Company, a company which greatly developed the quarries and marketed a large amount of the stone, principally in Washington. In 1874 the company became involved in litigation, and the quarries were closed for nine years. In 1883, the company was reorganized, and the work pushed rapidly forward until June, 1889, when the canal, upon which the company depended for transportation, was washed out and the quarries lay idle for a period of two years. In 1891 Mr. George Mann, of Baltimore, purchased the property and founded the present organization, "The Seneca Stone Company," which has worked the quarries during the last seven years.

The beds from which the building stones are now obtained lie west of Seneca Creek, on the left bank of the Potomac river, where the dip is some 15 to 20 degrees to the southwest. This inclination of the beds allows the quarrying to be carried on from the south and southwest without very much stripping and little or no binding from overlying strata. The openings show that the available material is distributed in workable beds, varying in thickness from eighteen inches to six or seven feet. These are separated from each other by bands of inferior material of different color and texture. The sandstone beds themselves differ very much, not only in color but also in hardness and texture. Some are fine-grained and can be wrought to a sharp arris; others are coarse-grained and may assume the character of a conglomerate. Interstratified with these grits are argillaceous shaly beds, which, together with some of the conglomeritic beds, are entirely

unfit for the better grades of work, and cannot compete with local stone for rough foundation work on account of the cost of transportation. In strata showing as wide variation as these do it is natural that only a portion of the material excavated is available, and there must necessarily be a considerable waste. Occasional clay holes in the lower grades, which produce unsightly holes on exposure, increase the waste, but these do not affect the character of the better grade of stone, since they may be avoided by a careful selection of the material. The bedding of the rock determines the direction and manner of operating the quarry, while the presence of two series of joints greatly facilitates the extraction of the material. These joints run normal and parallel to the strike of the bedding. The first stands perpendicular to the dip and the second is practically vertical, so that the blocks obtained are more or less rectangular. The distance between the joints varies from a few inches to several feet, but average satisfactorily for economical quarrying.

The texture of the stone which is placed upon the market is exceptionally good. It is very fine-grained and uniform and is not at all shaly, and shows little or no disposition to scale when exposed to the weather. The particles of quartz are evidently distributed through a fine, scarcely perceptible cement, and over the entire face there are very minute flakes of muscovite which brighten the general appearance of the rock. Occasionally in larger blocks there are seen small bands of coarser grain which indicate the bedding, and in a few instances this alternation in texture is emphasized by variations in the color of the cement.

One of the most valuable features of the Seneca sandstone is the extreme readiness with which the stone may be carved and chiseled when it is first quarried. It is then soft enough to be easily cut and the texture is sufficiently uniform to render the stone satisfactory for delicate carving. As is frequently the case with all building stones the rock after exposure loses the readiness with which it may be worked and becomes hard enough to turn the edge of well tempered tools. It is this hardening on exposure which protects and preserves the delicate tracery sometimes seen in the finer examples of dressing in blocks from these quarries.

The color of the Seneca Creek sandstone as furnished by the Seneca Stone Company varies from a homogeneous light reddish brown or cinnamon to a chocolate or deep purple-brown. When freshly quarried the colors are even brighter than after the rock has been exposed some time, the rock presenting tones of a light reddish fawn color. The color changes with the composition. With an increase in quartz the lustre of the rock becomes brighter and with an increase in feldspar the tone of the rock becomes grayer, while an increase in the amount of cement deepens the color.

The rock under discussion when studied microscopically is found to be composed of angular grains of quartz, microcline, plagioclase and muscovite. The first three of these minerals occur in more or less clearly defined polygons, which abut each other without interlocking. They show no uniform direction in the position of their longer axes. The same is true of the muscovite which occurs in long narrow shreds. This lack of interlocking between the grains causes large interstitial spaces which render the rock friable, porous and absorbent unless they are filled with some cement. In the Seneca stone the spaces are almost entirely occupied by a natural ferruginous cement which increases the strength of the rock. The relations between color, cement and porosity are indicated in the first two determinations by Page, given below. The individual grains are covered with films of iron oxide and there seems to be no evidence of enlargements due to the secondary deposition of silica. The plagioclase grains show some alteration, but those of the microcline are usually fresh and unclouded by decomposition products. Since the plagioclase is present in very subordinate amounts its alteration does not materially decrease the strength of the rock.

A cursory examination of some of the old buildings made of stone from Seneca Creek leaves the impression that at least part of the rock from this locality is unsuitable for fine buildings because of its low crushing strength and its tendency to scale. This apparent defect in the rock arises from two causes, the lack of care in the selection of material, and in the cutting of the blocks so that they will rest parallel to their bedding when set in the buildings. Material where such

scaling appears does not represent the better grade of Seneca stone but is coarser, showing more evidences of cross-bedding, and it is also much richer in mica and poorer in cement. There seems to have been a constant tendency among the earlier builders and stone cutters to place the rock, not on "bed," but on "edge." Many of the prominent structures which now give evidences of flaking or spalling clearly show all of the defective blocks to be on "edge." In all rock like the poorer grades of sandstone, such a position speedily brings out the inherent weakness of the rock. The only determinations of crushing strength available, prior to the present study, were made many years ago by Dr. Chas. G. Page and published by Walter R. Johnson [1] in the American Journal of Science. These give the average crushing weight per square inch as 2691 pounds. This value was obtained on two separate specimens, one of which was from the Smithsonian Institution. The fact that both rocks give the same values indicates a marked uniformity in the strength of the better grades of rock. The tests recently made show the strength per inch as high as 18,625 pounds per square inch (see below).

The weight and disintegrating effects of frost upon the Seneca sandstone were carefully studied by the Brard method before the stone was accepted for the Smithsonian Institution, and we have as a result of Dr. Page's [2] investigation the following determinations:

	Specific gravity.	Lost by frost in grains.
Dark red Seneca sandstone (similar to Peter's)	2.672	0.70
Light Seneca sandstone, dove-colored	2.486	1.78
Dark coarse sandstone, of Seneca aqueduct, Peter's quarry	not ascertained.	5.60
Sandstone four miles above No. 2 D, Peter's next west Beaver Dam quarry	not ascertained.	1.58
Dark sandstone, from quarry near Woods' residence	not ascertained.	3.94

The specific gravity of these rocks indicates that the weight per cubic foot of the stone is 154 to 165 pounds. These figures seem to

[1] Comparison of Experiments on American and Foreign Building Stones to Determine their Relative Strength and Durability. Amer. Jour. Sci., 2 ser., vol. xi, 1851, p. 7.

[2] Report of the Board of Regents Smithsonian Institution, Senate Doc., 30th Congress, 1st Session, No. 23, pp. 21-22.

FIG. 1. SANDSTONE QUARRY, EMMITSBURG, FREDERICK COUNTY.

FIG. 2. SANDSTONE QUARRY, SENECA, MONTGOMERY COUNTY.

indicate that the Seneca rock is slightly heavier than the usual run of brownstones, which, according to the table given by Hopkins, range from 127.5 to 166.1, with an average of 161.4 pounds. In structures the Maryland and Pennsylvania stones will range between approximately the same limits.

The various tests recently conducted by the Survey are very favorable to the Seneca rock. The specimens examined were in two-inch cubes cut from stock furnished to one of the stone yards of Baltimore. The figures below thus represent the average run of the quarry and not especially selected stock.

Simple crushing.	Absorption.	Freezing.	Crushing after freezing.	
			Crack.	Break.
......	2,368	0.006	73,700	74,500
72,280	....	....	......	......
......	2,530	0.012	65,840	69,500
69,000	....	....	......	......
67,560				
65,240				

The mineralogical and chemical composition leave nothing lacking as to the promise of permanency in the Seneca sandstone under the action of atmospheric agents. There are no deleterious minerals in the carefully selected stone which may injure its wearing power, and the chemical analyses show that the constituents are in stable combinations. The microscopical examinations also show (Fig. 14, p. 97) that the cement firmly binds the interlocking grains without leaving any considerable interstitial spaces in which moisture may lodge to destroy the integrity of the rock. This lack of porosity is shown also in the slight loss by freezing, as given in the above tables.

The best evidence of durability is found in the structures which have been made of this material. Owen reports (1847) that "by close inspection of slabs exposed now 20 years to atmospheric agencies and severe mechanical friction, the mark of the dressing-chisel is still sharply imprinted in the surface. On the perpendicular wall of the aqueduct, where the water has been oozing through the joints and trickling down its face, forming an incrustation of carbonate of lime,

[1] The Building Materials of Pennsylvania, No. 1 Brownstone. Appendix to the Ann. Rept. of Penn. State College, Official Document No. 22 for 1896, pp. 30-31.

one may observe, where this calcareous crust has scaled off, the grooves and ridges of the surface still nearly as distinct as when the block first came from the hand of the stonecutter.

"The angles and edges of the keystones of the arch, placed under these most unfavorable circumstances, are sharp and entire. Only one or two blocks of this work of 20 years' standing show sign of decay; but these seem to be such as either have not been well selected, or have been placed on the edge in the wall.

"Even the tow-path of this aqueduct, over which the horses pull and mules have been traveling 20 years, is still unimpaired. Even the corners around which the heavy lock-gates swing, show no signs of chipping."

Merrill later (1891) corroborates these observations and says: "On blocks of the stone in the aqueduct of the Chesapeake and Ohio Canal which have been constantly permeated by water every season for fifty years, the tool-marks are still fresh and no signs of scaling are visible other than are produced by too close contact at the joints. . . . The Smithsonian Institution erected in 1848 to 1854 from this stone, shows few defects from weathering alone, and these only in those cases where they might have been avoided by judicious selection."

No discoloration has been noticed in the rock beyond the darkening which gradually and uniformly takes place on exposure.

Minor Areas.

Throughout the entire extent of the Triassic as exposed in Maryland there are small local quarries developed to supply the demands for foundations and occasionally for more pretentious building. The general demand, however, is more than overcome by the cost of transportation in all but the most favorably situated localities. There are many occurrences which will prove of value as the country becomes developed and improves its facilities for distributing its resources. Among the most promising of these smaller openings is one located near Taneytown and owned by John Yingling. This quarry is situated on the western side of a little hill on the road leading from the Emmitsburg pike to Harney, not far from the former. The rock exposed is more feldspathic than any of the Triassic sandstones now

worked in the state. It is bright gray and gives a pleasing impression, which is in accord with the present demands for light and cheerful trimmings. The stone has been tested and the crushing strength and absorption for two-inch cubes is as below.

	I.	II.	Absorption.
Crack	67,900 pounds.	94,000 pounds.	0.004
Break	94,000 "	109,400 "	

The rock is, therefore, strong and when manipulated properly may be extracted in blocks of sufficient size to meet ordinary demands. The means of drainage and the opportunity for dumping waste are favorable, while the distance from the quarry to the railroad is not far enough to render competition unsuccessful. The smaller quarries which have been worked spasmodically include the quarries just north of Emmitsburg, and several openings about Taneytown, Thurmont and Union Mills.

It is not improbable that suitable rock might be found in the vicinity of Bruceville, where the railroad facilities are especially favorable.

Washington Junction.—The only other source of red and brown sandstone from the Triassic formation of Maryland, which enters into competition with the Seneca stone, is near Washington Junction in Frederick county. Here the Washington Junction Stone Company, capitalized at $30,000, carries on considerable work in extracting and dressing the red, brown and variegated sandstones. The present operators began work in 1892, and have continued quarrying almost continuously ever since, furnishing much stone for such buildings as the Fort McHenry Hospital, Baltimore, churches at Forest Glen, Maryland, and Winchester, Virginia, and many houses in the better part of Washington.

The beds from which this sandstone is obtained dip gently to the west, and thus afford opportunity for the economical extraction of the stone. Blocks 20 x 6 x 4 feet may be obtained if the demand and the machinery warrant. The stone does not differ noticeably from that furnished at Seneca but shows the same pleasing color and texture already noticed in the latter place. The quarries are well equipped with saws, rubbing beds, polishing machines, etc. The chief

drawback in the location of this opening, which is a mile and a half from the railway station, is removed by a small spur track which extends from the quarry to the station and to the wharf on the Chesapeake and Ohio Canal.

The general mode of working the quarry is shown in the accompanying figure (Plate XXIX, Fig. 2), which inadequately represents the ledge whence the material is obtained.

PALEOZOIC SANDSTONE.

Among the various later Paleozoic formations there are four which develop well marked sandstone series. These are the Pottsville, the Pocono, the Monterey and the Tuscarora. None of these have been worked to any considerable extent as building stones, because of the lack of demand and transportation facilities.

The Pottsville Formation.—The Pottsville is the lowest division of the coal measures and forms the mountain ridges which border the coal basins. It consists of sandstone and conglomerates interstratified with sandy shales in which thin beds of coal are locally developed. The sandstones are usually coarse-grained and conglomeritic, with marked evidences of cross-bedding which are irregular in extent and distribution. The individual pebbles, frequently very small, are held together by a siliceous cement, which indicates great durability for the rock. Unfortunately such a cement renders the working of the stone both difficult and expensive. It is probable that this material will never become of economic importance except in the supply of local demands for foundations, steps and occasional door sills.

The Pocono Formation.—The Pocono formation is very similar to the Pottsville and consists mainly of hard, thin-bedded flaggy sandstones which occasionally become sufficiently conglomeritic to produce confusion between the two formations. The sandstones of the former have received but little attention and have been used only occasionally as a supply for flagging. It seems quite probable that as the demand for building stones increases the flags, which are well developed in places, may come to be of some importance.

The Monterey and Tuscarora Formations.—These two formations have a considerable development in Allegany and Washington

FIG. 1.—MONOCACY AQUEDUCT, WHITE QUARTZITE FROM BELT'S QUARRY.

FIG. 2.—SANDSTONE QUARRY, POINT OF ROCKS, FREDERICK COUNTY.

counties, where the stone has been used to supply the local demands. This is especially true of the area about Cumberland. Here the Monterey sandstone, which is of a buff-brown to yellow color, was the first to be introduced. It is the source of all of the sills, foundations and lintels for the older buildings. The most important structure in which it is exclusively employed is the Episcopal church. Time has shown that the very property for which the stone was first chosen, viz., the ease with which it is cut, is detrimental and that it, together with the clay holes which seem to be developed frequently, leads to the ready disintegration of the rock, so that many of the steps, sills and foundations of the older buildings are in quite a dilapidated state. Where this stone was used in curbing the blocks have become rounded, or broken or deeply worn. The stone itself when dressed presents a very pleasing appearance, especially in trimmings, where it coincides with the present tastes in architectural work. It is quite possible that by careful selection good material might be obtained from one of the several quarries in Cumberland to supply the demands for a light gray or yellow trimming stone. As a clew in the choice of material it may be stated that as the number of fossils decreases the rock becomes harder.

Although the Monterey has not proved altogether satisfactory about Cumberland there are other points in the distribution of this formation where it seems probable that good material may be obtained. The best of these is the quarry owned by Mr. B. S. Randolph of Frostburg, which is located in Washington county near Dam No. 6 of the Chesapeake and Ohio Canal. The opening, which was made for glass sand and not for building stone, is in the form of a tunnel from thirty to forty feet deep, and is situated about 800 yards back from the canal and from 400 to 500 feet above it. The stone is of clear creamy-white color and would make a bright trimming or structural material. At first sight the rock looks as though it is too friable and not strong enough to endure pressure, but the experiments show that in two-inch cubes it has a crushing strength of 73,780 pounds on edge and 75,600 normal. This indicates that the first impressions are incorrect and that the rock is capable of withstanding any ordi-

nary pressure. The purity of the rock is attested by the following analyses made by O. Creath of Pottsville, Pa.:

	1.	2.	3.	4.
SiO_2	99.255	99.558	99.398	97.55
Al_2O_3	.610	.341	.473	2.44
CaO	.110	0.81	.102	.01
MgO	tr.	tr.	tr.	
FeO	......	......	.027	tr.
FeO	.025	0.20	......	......
	100.000	100.000	100.000	100.00

When it was found that the Monterey sandstones were not as durable as expected and that they soon became disfigured by exposure, attention was directed to the harder white sandstones of the Tuscarora which are exposed in Wills Mountain just west of Cumberland. The ledge here exposed has a thickness of some 300 feet, but the solid rock has not yet been quarried, since the demand is more readily supplied by utilizing the many detached blocks which cover the slopes of the mountain. At the present time this stone is used for foundations and trimmings in all of the better class of buildings in Cumberland, and its character is well shown in the Presbyterian church. The rock varies somewhat in texture and firmness according to the different beds, but on the whole shows unusual uniformity. It is bright gray in color and is composed entirely of fragments of quartz, which are themselves cemented by a siliceous cement, causing the rock to be in reality a quartzite rather than a sandstone. Feldspar and mica are also found in the rock. Few imperfections were noticed and for one of such siliceous character the rock seems to be very free working.

The chemical composition, as might be inferred from the mineral contents, is largely silica. Professor C. F. Chandler[1] in his report on the mineral resources of Cumberland gives the following analysis:

Silica	98.35
Sesquioxide of iron	0.42
	98.77

[1] See Tenth Census, vol. x, Report on Building Stones, p. 178.

while a more complete one furnished by the present operators is as follows:

Silica	98.00
Al_2O_3	.65
Fe_2O_3	.15
CaO	.40
MgO	.21
Alkali	tr.
Water and organic	.50
	99.91

The Tuscarora sandstone unlike that of the Monterey shows great durability in whatever position it may be placed, and it is accordingly used in almost all of the local work on the embankments of the Chesapeake and Ohio Canal and in foundations wherever there is a considerable superstructure. It is also used to great advantage for paving, curb-stones, steps and trimmings.

Besides the prominent sandstone formations of the Paleozoic already mentioned and that of the Cambrian considered below, there are scattered throughout the series numerous small beds of sandstone which are sometimes utilized to supply local requirements. The quarries which have been opened are scarcely worthy of the name and the product from all of them is insignificant.

Cambrian or Mountain Sandstone.—There extend across the state two parallel bands of dense quartzites which form the Blue Ridge and Catoctin mountains. These quartzites were originally porous sandstones, which have subsequently been thoroughly consolidated by a dense siliceous cement. Similar rocks also occur in the small detached area of Cambrian sandstones which forms Sugar Loaf Mountain. The rock has never been brought prominently into the market, although it has been used quite extensively for railroads, canals, roads and a few individual buildings. It is not known when the first work was done here, but according to Scharf the quarries at Sugar Loaf were operated quite extensively prior to 1830 to furnish stone for the old canal. At this time there was a tramroad several miles long extending from the quarries to the canal. The rails were striplings and the tram cars were hauled by horses. This little railroad antedated the Baltimore and Ohio and has practically disappeared, road

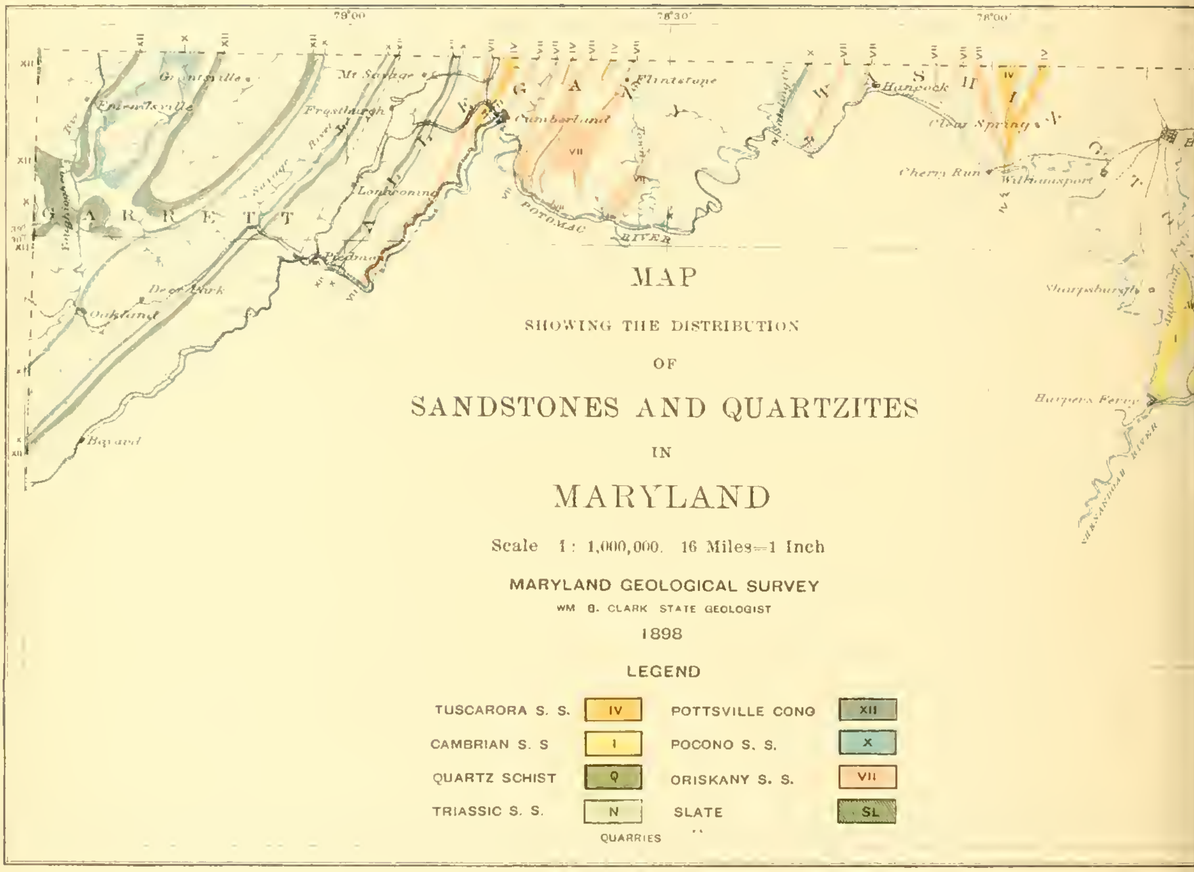
bed and all. During the succeeding decade the Sugar Loaf stone was used in the Baltimore and Ohio Railroad, which has continued its use occasionally ever since.

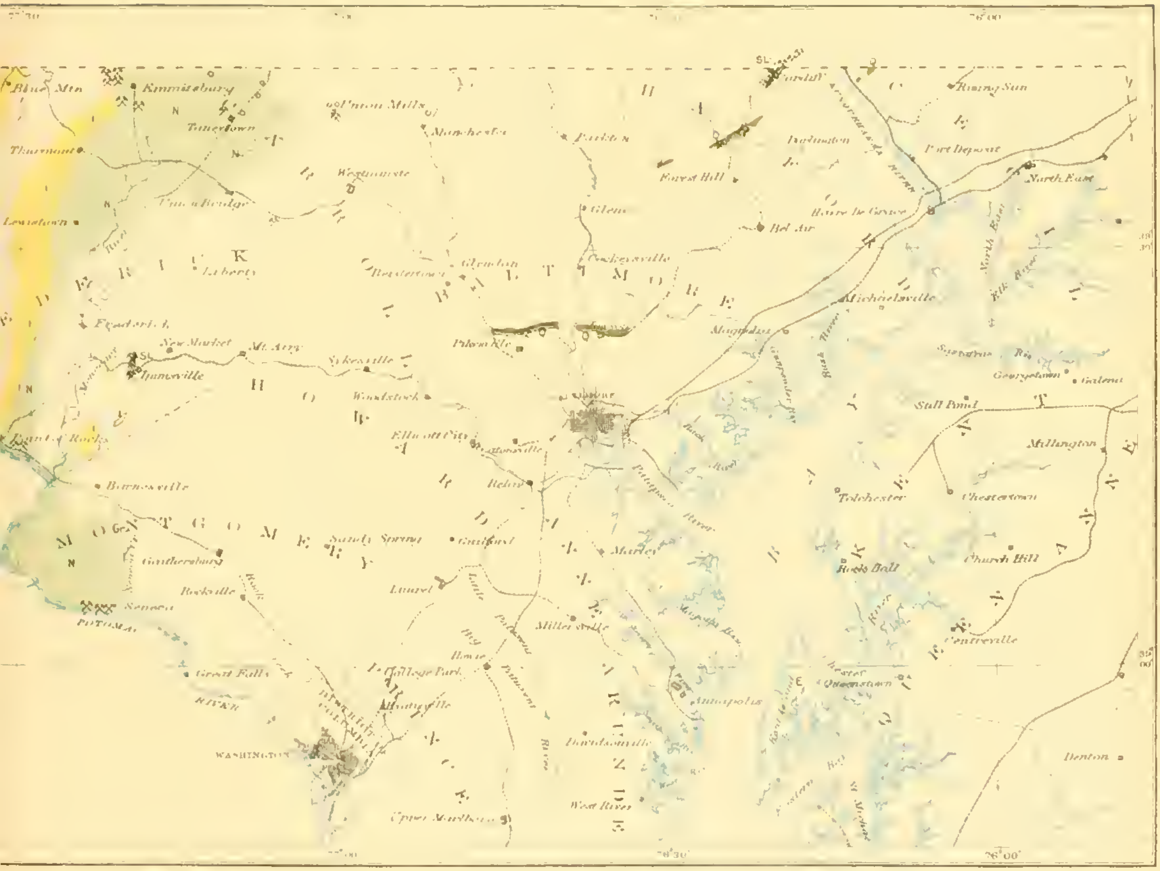
Other quarries have been opened in a small way along the Western Maryland Railroad to supply the demands for good road metal and small quarries have been operated by the Mount St. Mary's authorities at Emmitsburg. The latter furnish a stone of dense, even texture in which there can be little absorption and little consequent loss by the action of frost. The crushing tests show that its strength is exceptionally great as a two-inch cube sustained a weight of 93,900 pounds before cracking and 104,200 pounds before breaking. In buildings the rock appears of a bright fresh gray color which darkens but little on exposure. Its general appearance is well shown in the recent additions to the buildings at Mount St. Mary's. The siliceous character of the rock renders it difficult to work in other than the natural face, but its durability, strength and compactness render it unsurpassed where great permanence is desired.

There are within the area of Cambrian sandstone above enumerated many exposures of rock which deserve more careful investigation and which no doubt would prove of service if the transportation facilities were at hand. At present the demand is not enough to warrant any workings beyond the occasional operations carried on at the McGill Belt Quarry at the base of Sugar Loaf Mountain and the incidental quarrying at Mount St. Mary's, near Emmitsburg.

MICACEOUS SANDSTONES OF EASTERN MARYLAND.

Scattered over the northeastern portion of Maryland in Baltimore and Harford counties are several exposures of highly micaceous quartzose rocks, which were originally sandstones, but which have now undergone considerable change through dynamic metamorphism. These are most characteristically developed in Setter's Ridge along the Green Spring Valley, ten miles north of Baltimore, and on the Baltimore and Lehigh Railroad near Pylesville, and eight or ten miles south of the Mason and Dixon line where the railroad crosses Deer Creek.


MAP
SHOWING THE DISTRIBUTION
OF
SANDSTONES AND QUARTZITES
IN
MARYLAND
Scale 1 : 1,000,000. 16 Miles=1 Inch
MARYLAND GEOLOGICAL SURVEY
WM. B. CLARK STATE GEOLOGIST
1898
LEGEND
TUSCARORA S. S. IV
CAMBRIAN S. S I
QUARTZ SCHIST Q
TRIASSIC S. S. N
POTTSVILLE CONG XII
POCONO S. S. X
ORISKANY S. S. VII
SLATE SL
QUARRIES
79°00′
78°30′
78°00′
G A R R E T T
Grantsville
Frostburg
Mt Savage
Cumberland
Flintstone
Lonaconing
Piedmont
Deer Park
Oakland
Bayard
POTOMAC RIVER
Hancock
Clear Spring
Cherry Run
Williamsport
Sharpsburg
Harpers Ferry



LITH BY A HOEN & CO. BALTO

Deer Creek Sandstones.

At the station known as "The Rocks," the Baltimore and Lehigh Railroad and the Deer Creek pass through a ridge of highly metamorphosed hard micaceous sandstones in a gorge 350 feet below the summit. This ridge extends in a northeasterly and southwesterly direction for a distance of ten to twelve miles and forms a part of the folded phyllite series which are probably of Cambrian age. The sandstone of which it is composed lies geologically some distance above the base of the series and below the bottom of the Peach Bottom slates.

The stone is a micaceous sandstone rich in quartz which locally becomes clearly conglomeritic. It contains more or less white mica, chlorite and bluish kyanite which are the product of secondary crystallization due to the metamorphism. The schistosity is well marked and in many instances minute flutings and crinklings are noticeable, producing in a cross section of the rock a somewhat pleasing figure and lustre. This stone has long been used in the surrounding country for foundations, sills, steps, and hearthstones, and its fire-proof character was early appreciated by Dr. Thomas Johnson of the U. S. Army. In 1891 a company known as the "Maryland Granite Company" was organized to develop the material as a building stone. Cables were strung to deliver the stone on board the cars and considerable work was accomplished in preparing for quarrying. The company soon ceased operations, either because satisfactory rates were not made with the railroads or because there was no demand for the stone, which was not a granite either in character, origin or even in appearance.

In the northern extension of this ridge, about Pylesville, the rock becomes less conglomeritic and micaceous. It has never been worked for any purpose in this vicinity, but if the demand should arise it is highly probable that the area will offer suitable material for a medium grade building stone.

Setter's Ridge Quartzite.

Setter's Ridge is a prominent topographical feature along the south bank of the Green Spring and Mine Bank valleys from Green Spring Junction on the Northern Central Railroad to Summerfield on the

Baltimore and Lehigh Railroad. It is composed of a thin series of highly micaceous beds of quartz-schist which are sharply separated from the overlying limestones on the north and merge more or less gradually into the gneisses on the south. "Whatever the origin of the quartz-schist may have been it is closely allied to the gneiss into which it grades. . . . It is not improbable that this peculiar rock represents a facies of the gneiss produced by some dynamic agency, for it always shows the effects of intense mechanical action and motion." This formation never attains any considerable thickness and it always occurs as a series of beds of quartzite of varying thickness, separated by parallel layers of muscovite, in which are emplanted numerous shattered tourmaline crystals which appear stretched and drawn out in the manner described and figured by Williams.[1] The readiness with which the quartz-schist cleaves into broad slabs well fits it for flagging. It is quarried at a number of points in the Green Spring valley, but it is most extensively worked at the Shoemaker quarries about one-half mile west of Stevenson Station. From here it is transported for considerable distances and may often be seen in foundations and bridge abutments. It is a rock of low quality, and quarried in a careless way and at present is of little economic importance.

Slate.

GENERAL DISTRIBUTION.

When Tyson made his first reconnaissance of the state as Agricultural Chemist in 1859 few industries appealed to him more strongly or seemed to promise greater returns than the quarrying of slate. That his view, which was based on the fire-proof quality of slate roofs alone and did not take into account their durability or pleasing appearance, has not been fully realized, is due to factors beyond his control. Other states have gained the advantage by superior mercantile energy. At the time of his visit three quarries were in operation in Harford county, while smaller openings had been made for slate at Hyattstown, Ijamsville and Linganore. None of the latter are now in active operation, but the Ijamsville area will be treated briefly after a discussion of the Peach Bottom region.

[1] Guide to Baltimore, p. 104.

THE PEACH BOTTOM AREA.

The slate produced in the quarries of the Peach Bottom district of Maryland and Pennsylvania is the most widely known structural material manufactured within the limits of the state. Unfortunately Maryland has received little credit for its share in the industry although almost all of the productive quarries are situated within its limits. This apparent injustice has arisen from the fact that the shipping point for most of the quarries and the residence of many of the operators is Delta, Pennsylvania, a town lying at the foot of the ridge which supplies the stock for the manufacture of slate. Delta is so much better known than its Maryland associate, Cardiff, that mail is received through the Delta postoffice by inhabitants living scarcely one hundred yards from the Cardiff office.

The topographic relations between the town and the quarries are particularly favorable for the shipment of slates and the establishment of a prosperous community. The town is connected with the principal cities of the Atlantic seaboard by the York and Peach Bottom Railroad (broad gauge) which forms a portion of the Pennsylvania system, and the Baltimore and Lehigh Railroad (narrow gauge) which runs from Cardiff to Baltimore. The latter railroad, because of its small cars and narrow gauge, permits shipment of slates no farther than Baltimore, where trans-shipping to broad gauge cars is necessary. When it is broadened, as is now contemplated, the shipments from Cardiff will no doubt increase and Maryland will receive a more just proportion of the credit for the manufacture of one of the most perfect slates produced in the world.

The quarrying of slate in the Peach Bottom area is divided chronologically, according to the nationalities of the quarrymen and the methods of quarrying, into two well defined epochs, the first ending with the arrival of the Welsh immigrants during the years 1845 to 1860. During the first period the workers were not professional quarrymen, skilled in the manufacture of slate. The Welsh, on the other hand, were trained in the art from their childhood, and many of them are known to have been employed in the Festiniog quarries of northern Wales. There is no information at hand from which we may

learn when the presence of valuable roofing slates was first recognized in this area or when the first material was taken out for roofing purposes. According to the local tradition, which is subject to some doubt, the slates were quarried as early as 1750. The building on which these slates were laid was destroyed a few years ago and the inferences concerning its age are based on a series of deeds and family papers which seem to indicate the date of construction as 1749 or 1750 and the source of the material as some point on the ridge not far to the north of the Mason and Dixon line. The first authentic evidence of quarrying is the slate recently removed from the roof of the old Slate Ridge Church, known to have been built in 1805, which was torn down in 1893. The slates from this old roof which had been exposed to the atmospheric agents of degeneration for eighty-eight years show no change in color or firmness, although some of them were covered by lichens and other vegetable growths. The slabs of slate used ranged in size from large pieces three feet square in the lower courses, to small ones three by seven or eight inches near the ridge pole. Some of the larger slabs have been preserved by the quarry superintendent to show the great stability of their stone, even when poorly prepared and poorly laid. These pieces are irregularly cut and more or less unevenly split. The stock used is not equal to the first or even the second quality of slates furnished at present. Prior to the coming of the Welshmen with their improved methods of working, the limit of the quarrying was the "Big Red" clay[1] which is the limit of weathering and the point to which the ledges are now stripped. When the hard rock was reached in earlier times, work ceased, since explosives were not used to cut a "head" or to loosen the rock. The earlier workers also had no adequate methods of trimming their slates and tradition says that their splitting chisels were mattocks.

During this period of early work the most prominent operators were Messrs. Carmen and Docker, two Englishmen who obtained a lease of the land, including the quarry now operated by R. L. Jones, a short distance north of the state line. These gentlemen, with Peter Williamson as foreman, opened and operated a quarry from 1812 to 1817,

[1] Shown at the point of stripping reached by the men in Plate XXXI, Fig. 1.

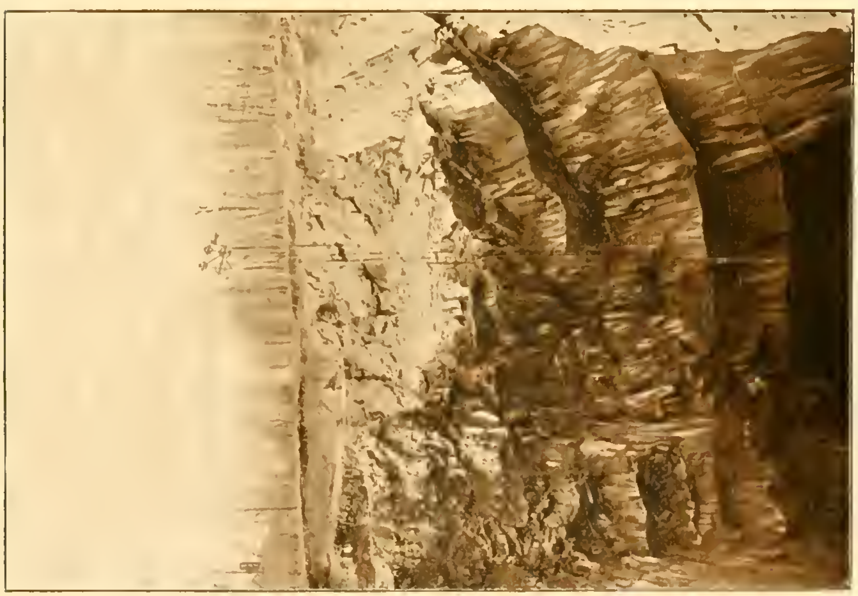


FIG. 1.—PROCTOR BROTHERS' QUARRY.
CAMBRIA, HARFORD COUNTY.

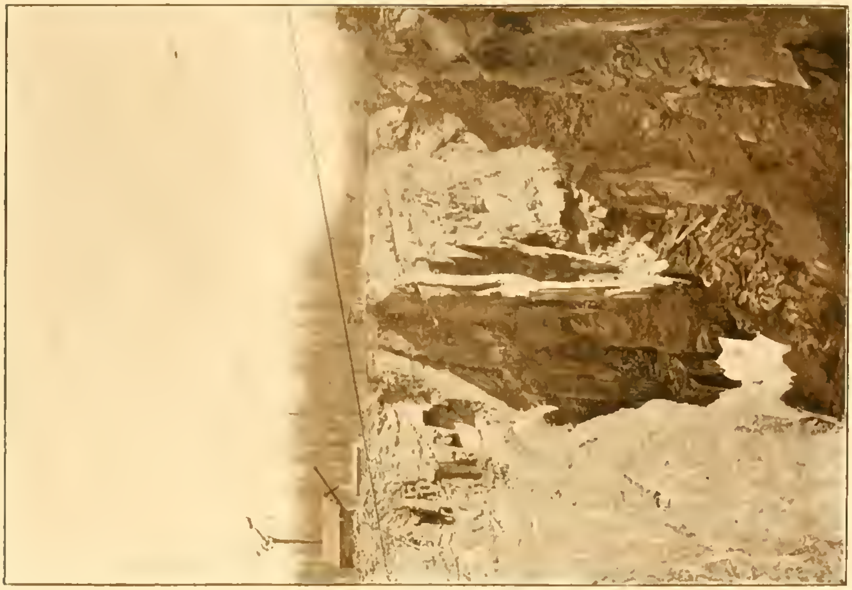


FIG. 2.—PEACHBOTTOM-EXCELSIOR-PEERLESS QUARRY.
CAMBRIA, HARFORD COUNTY.

when it was abandoned because competition with the Welsh product was unremunerative. The Welsh slate at this time was shipped to America as ballast and admitted free of duty.

About the same time (1812) Mr. Sinclair made an abortive attempt to produce slates successfully on the "A. B. Miles property." The location of his opening was between two quarries which have subsequently been worked with greater or less profit. Nothing is known of this operator beyond the facts enumerated, except that he seems to have left the country about 1817 at the time when Carmen gave up his work. During the seventeen years from 1817 to 1834 no work was done along that portion of the Peach Bottom district which lies west of the Susquehanna. Mr. Williamson, however, seems to have removed to Lancaster county and to have carried on the manufacture of slates in a small way during the interval. The property whence he obtained his material belonged to a Jeremiah Brown.

In the fall of 1834 Carmen returned to Delta and wished to sell his lease as the quarry had been so unremunerative that he had changed his business. His former foreman, Mr. Peter Williamson, finally bought the lease and began operations which have continued in this locality up to the present. The rental paid by Mr. Carmen to Mr. McCandless for the entire tract was \$36 a year and the price paid by Mr. Williamson for the land in fee simple was \$12,000. Slate at this time, whether from Welsh or American quarries, sold at about \$20 a ton, or approximately \$5 a square, as slate is now figured. The first lease to Welsh immigrants was granted by Williamson about 1845, when two families by the name of Davis (an uncle and nephew) began operations after the improved methods with which they were familiar in the old country. The Davises took a lease of a portion of the ridge just north of the Mason and Dixon line and worked a quarry for two years, when the same was leased to Roland Perry, a recent arrival from Wales. Mr. Perry greatly developed the industry, and soon had in his employ a force of sixty to seventy-five men, who turned out a highly improved grade of slate. About the same time John Humphrey, another prominent operator of the area, with others worked a quarry near West Bangor and became very successful. Both Perry and Humphrey cleared about \$50,000 or \$60,000 each, during

their operations. Their method of working the quarries seems, however, to have been somewhat faulty as they were inclined to follow down a "vein" without sufficient breadth, until at a depth of 160 to 176 feet the loosened and insufficiently supported top rock either caved in or rendered the working of the quarries exceedingly dangerous.

The first quarry south of the state line operated by the Welsh methods was opened by Mr. Robert Griffith some time in 1847 at the location of the present York and Peach Bottom quarries. This was the only firm working south of the Mason and Dixon line during the succeeding decade. The power until 1855 was supplied by horse windlass, when a steam engine was added to the equipment in order to pump the water from the pit. Griffith successfully operated the quarry for several years. At his death the work was continued by Samuel M. and Hugh C. Whiteford, his administrators, who made and sold a large amount of slate. The quarry leased was then sold to Isaac Parker of New York for $18,000. This property, together with that operated by Proctor Bros., and all the slate lands extending and bounding on the Mason and Dixon line on the east, belonged to Thomas Hawkins, who entered it previous to 1776.

Thomas Proctor came to this country about the same time with Carmen, Docker and Sinclair. As general managers, Sinclair and Proctor opened a quarry on the Hawkins property, on the north side of the road 200 or 300 yards northeast of the now York and Peach Bottom quarry. In the meantime Thomas Proctor married Elizabeth, only daughter of Thomas Hawkins, and became possessed of part of Thomas Hawkins' estate and built on it, amongst other structures, a stone springhouse, which is still standing covered with slate from this quarry. This, according to one tradition, was the first slate roof put on, and antedates that of Slate Ridge church which was taken from the same quarry in 1805. This quarry was operated by a few hands in 1812, as the father of Mr. Wm. G. Coulston brought from them a flag for a doorstep, dressed about 5 feet long, 2½ feet wide and 3 inches thick. The hands put it down for him and it remains the same to-day. The vein was narrow and did not work to

profit and was abandoned. Mr. Proctor tried other places without success, and it was left to his grandsons to profit by his oversight.

During the year 1858 Richard Griffith, of Philadelphia, no connection of the above named Robert Griffith, opened a quarry in the lower portion of the northwest side of the ridge, not far from the present town of Cambria. This prospecting opening was sold to a syndicate composed of Samuel Bottime (President), W. P. Bolton (Superintendent and Local Manager), and others, who attempted to operate the quarry. The whole project was abandoned the following year. The failure was due to the selection of a place of opening on the very edge of the slate formation instead of at some point on the top of the ridge nearer the center, where the stock is much better. This syndicate at that time held land which carried the best beds of slate known at present, since some ten years later, April 8, 1868, the present "Peach Bottom Slate Company of Harford county, Maryland," rented their site from this company on a thirty year lease. The Peach Bottom Slate Company worked on the lease for a few years when at the death of one of the owners, according to the laws of the state then in force, the entire property was offered for sale. Following the advice of Col. Webster of Bel Air, who was interested in the company, the lessees bought that portion of the estate which they had held by lease and in 1878 were incorporated as a company with the above title.[1]

[1] The history of this property, which contains the most active quarries, is quite involved. After the property which Richard Griffith bought of the Whiteford estate proved worthless, the 25 acres adjoining, which includes the Peach Bottom, Peerless, and Excelsior quarries, were sold by Michael Whiteford to John Morrison for $500. (His eldest son says that his father Michael received no money, but took it out in shoemaking and mending for his family and bond servants). Morrison willed the land to his daughter, who married Thomas Wright. Mrs. Wright offering the land by an agent, Joseph D. Wiley, found no bidders, and subsequently bequeathed it to her five daughters, one of whom sold her lots to a company composed of John Humphrey, Richard Rees, Owen Owens, Benjamin Williams and ——— Jones. One other daughter sold her portion to a company—Thomas W. Jones, John Parry, William Thomas and William Parry. This lot was sold by the minor heir; in consequence the purchasers afterward had trouble in perfecting their title. The price of each of these lots or portions was $1200.

In the fall of 1870 John Parry, William W. Thomas, Thomas W. Jones, William Parry, Catherine Jones, and others formed the Welsh Slate Company which leased four acres adjacent to that of the Peach Bottom and opened the "Hickory Hill Quarry," subsequently worked by the Peerless Slate Company of Pittsburg for a term of ten years ending in July, 1898.

In 1873 or 1874 the Welsh Slate Company through Mr. Parry bought the land for $12,000 and other considerations, a figure which shows a marked increase in the valuation of the property since 1850, when 25 acres, including all of the quarries now operated was offered for sale for $1,200 and found no takers. Since the property bought by Mr. Parry was deeded by a minor there developed a great lawsuit concerning the ownership of the property and it was only after considerable expense that the company cleared its title to the land.

The Excelsior Quarry was first operated by a small company, who bought a little land in 1860 and operated until the spring of 1861, when the work was stopped by the enlistment of most of the owners, who themselves worked in the quarries. This land was sold to Isaac Parker after the war and later come into the possession of William E. Williams & Co., who leased it to two parties soon after on short leases. The quarries have been operated under leases ever since the land became the possession of the present owners. The quarries operated at present by Proctor Brothers, who started work in 1893, was first operated about 1868 but was not worked very much until under the present regime.

In 1880 Persifor Frazer[1] in his report on the Peach Bottom slates in York County and Maryland says that the following quarries succeeded each other beginning at the state line and proceeding southward into Maryland at the time they were visited in 1877:

Kilgore & Co.'s, James Perry & Co. (has been idle several years); Wm. E. Williams & Co. (leased and operated by the York & Peach Bottom Co.); Wm. C. Roberts (owned and operated by Proctor Bros.); John Humphrey & Co. (Peach Bottom Slate Co.); Thos. W. Jones & Co. (idle for several years, now owned by Peerless Slate Co. who

[1] Geology of Lancaster county, Second Geological Survey of Pennsylvania. CCC., Harrisburg, 1880, pp. 182-190.

have made a new opening recently); John W. Jones & Co. (8 miles south of state line along the ridge); Hugh E. Hughes & Co. (idle about ten years).

The accompanying sketch shows the location of the abandoned and active quarries within the State of Maryland at the time of their study for the present report in 1896.

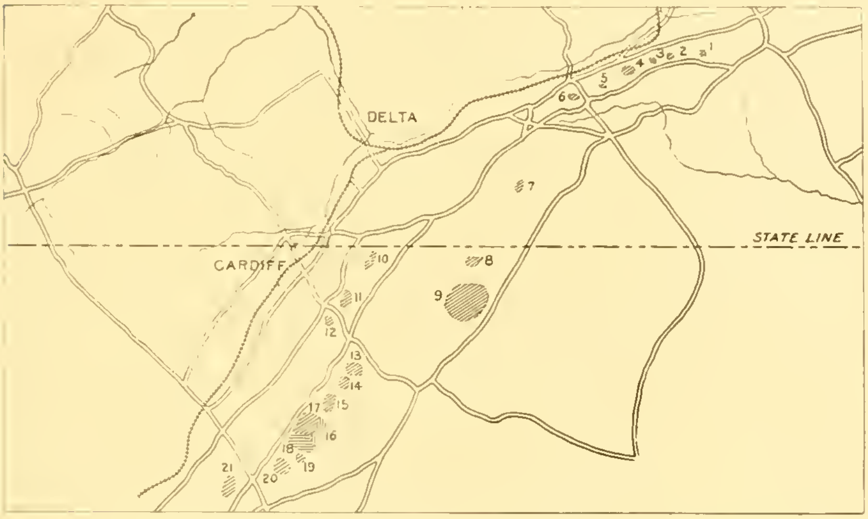


FIG. 19.—Sketch map of Peach Bottom Slate area.

Slate Quarries at Delta, Pa.

1.	Faulk Jones & Son,	(w)	11.	Scarborough's Quarry,	(a)
2.		(a)	12.	Baltimore & Peach Bottom,	(a)
3.		(w)	13.	Henry's Quarry,	(a)
4.	R. D. Jones & Co., Tunnel,	(w)	14.	York & Peach Bottom,	(w)
5.	E. W. Evans & Co.,	(w)	15.	Proctor Bros.,	(w)
6.	R. L. Jones,	(a)	16.	Peach Bottom,	(w)
7.		(a)	17.	Excelsior,	(w)
———————	State line.		18.	Peerless,	(w)
8.	Slate Springs,	(a)	19.	Aiken & Co.'s,	(w)
9.	Delta & Peach Bottom,	(w)	20.	Stubbs or Cambria,	(w)
10.	Schwab's Quarry,	(a)	21.	Baltimore & Peach Bottom,	(a)

(a) Abandoned. (w) Working.

The geological position of the beds, which furnish the slates of the Peach Bottom district, is in either the Hudson River or Quebec

series, probably the latter as determined by Professor James Hall in 1883 from fossils submitted to him by Dr. Persifor Frazer.[1]

The productive beds are thought to be the axis of a narrow overturned synclinal fold which is included within the phyllite formation, extending in a northeast-southwest direction across eastern Maryland. The stratigraphic position of the band is still in some doubt, since no detailed mapping of the area has ever been completed. Just below the slates, which form the top of the well-defined topographic features called the "Slate Ridge," is a band of talcose chlorite slate which runs parallel to the roofing slates on either side of the ridge. These talcose slates are in turn underlain by a metamorphosed quartz conglomerate which resembles that of the exposures at the Rocks of Deer Creek. This quartzitic conglomerate wraps about the end of the slate formation some fifty feet below the exposure of the slate. To the southward the bands of conglomerate from either side coalesce and form a continuation of the slate ridge, which extends outhwesterly across the Broad Creek at Pylesville, where Broad Creek has cut a well-defined gorge. While few, if any, observations have been made upon the true bedding of the slates and while no satsifactory contacts have been found in recent studies in the area, the workings along the ridge seem to point conclusively to the fact that this syncline is somewhat overturned to the east, so that the dip of the westerly side is practically coincident with the cleavage, as is claimed by the quarrymen. The slate belt itself forms a narrow zone beginning a short distance southwest of the road running from Cambria to Prospect and extends in a northerly direction more or less parallel to the "Slate Ridge" through Maryland and York county, Pennsylvania, to the Susquehanna river, which it crosses. There is a short extension of the formation east of the Susquehanna in Lancaster county, which at times has been the most productive portion of the belt.

Throughout all of that part of the area which has furnished good slates the bedding is not clearly defined and the ledges of first-class material do not seem to present any continuous arrangement, suggesting valuable beds separated by non-productive ones. This lack of definition in the bedding of the stone renders it impossible to com-

[1] Trans. Amer. Inst. Min. Eng., vol. xii, 1884, p. 358.

pute with any degree of accuracy the thickness of beds or "veins." Some of the quarries produce good slate over a distance of a least 150 feet across the strike and their operations are limited not by the quality of the stone but by a short-sightedness during early operations which allowed the rubbish to be dumped upon the workable beds.

All of the quarries along the line show a great many series of joints which both aid and hinder the working of the quarries. The principal or bedding joints, as observed in the Proctor Brothers' opening (shown in Plate XXXI, Fig. 1) strike cross the cleavage and dip at an angle of 42° to the southwest. Similar bedding joints were observed in the Peach Bottom and York and Peach Bottom quarries (Plate XXXII). In addition to this most clearly marked jointing, there is a second series of joints dipping at an angle of 26° with the same strike and another set of joints which dip at about 80° to the northeast with their strike normal to the cleavage. These three systems free the rock in large rhomboidal slabs and they, if they existed alone, would be very valuable aids in quarrying the rock. Unfortunately besides these somewhat uniformly inclined joints there are a great many other jointing planes developed through the beds which do not seem to be conformable to any system of arrangement. They cut each other at all angles and intersect the plane of cleavage either acutely or with considerable obtuseness. In the York and Peach Bottom quarries there are sharply defined uneven jointing planes which leave the rock protruding like a series of folds whose axes lie parallel and separate from each other at a distance of one to three feet. The material on each side of the curved jointing planes (see Plate XXXII, Fig. 1) is of the same character and there is no evidence to warrant the assumption that there has been a direct bending into small folds either prior or subsequent to the development of the cleavage and the other jointing planes. The great number of joints and their intersection with each other at varying angles renders much of the material extracted unavailable for the manufacture of roofing slates or mill stock. While this is so and the amount of rubbish about the quarries is very great it is doubtful if there has been a greater portion of waste material than is common in slate quarries the world over. Another fac-

tor which must be regarded by practical operators working in the Peach Bottom area, is the presence of "flint seams" and "blue joints" which modify the manner of working the stone and frequently render much of the material worthless. The "flint seams" are of at least two classes; those of the first occur in long thin layers along the jointing planes where the two sides of the joint have been separated sufficiently to allow the deposition of quartz. The second class includes much more irregular deposits which occur in irregular masses varying from a fraction of an inch to several feet in diameter. These apparently represent zones of more intense crushing and subsequent deposition of quartz since it is a common saying among the quarrymen that the seams cleanse the rock and make the cleavage finer and truer. The "blue joints" referred to are really closed jointing planes in which chlorite has been deposited in more or less complete orientation with the chlorite of the body of the slates. The seams are not evident at first, but during the splitting and trimming of the slates develop as lines of weakness which render the pieces obtained of no value.

The most prominent feature in the texture of the Peach Bottom slates is the coarse fibrous arrangement of the particles which give to the stone an appearance somewhat suggestive of the fibre of petrified wood. This texture renders the slates much stronger in certain directions than they might otherwise be, but precludes the method of breaking the slates by sharp blows applied normal to the cleavage and makes the stock unavailable for milling purposes. The peculiar "fibrous" texture of the slate is indistinctly shown in Plate XXXI. Fig. 1, which represents the combined opening of the Peerless, Peach Bottom and Excelsior quarries. This also renders the use of the "plugging machines" and similar instruments of doubtful value. It has also been found more economical and feasible to saw the slates across their grain. The material prepared for market shows little or no variation in the nature of the stone employed, but the character of the finished product seems to vary somewhat in different quarries. Not only is there a difference in the skill with which the work is done, but the quarrymen seem to differ in the amount of care which they

exercise in sorting the first and second qualities. While different beds and different portions of the quarry furnish stock that differs in the ease with which it is worked and in the character of the finished product, the quarrymen say that good material may be obtained from all portions of the opening and at all depths below the zone of superficial weathering. In company with quarrymen from all regions the men hold to the belief that the rock improves indefinitely with the depth.

The color of the Peach Bottom slates is a deep blue-black which is absolutely unfading, as is shown by the color of slates which have been exposed since the beginning of the century. This fact alone places the product of the area among the best slates of the world. From this color there seems to be no variation in any of the well prepared material. It should be borne in mind, however, that slates, like broadcloths, when placed side by side with their texture in different positions show differences in their sheen and that these differences may become so marked that an impression of a variation in color is often given. Care must be exercised accordingly not only in the selection but also in the laying of the slates if the most desirable effect is to be obtained. The unfading quality of the Peach Bottom slates allies them with the products of the Maine and certain of the Vermont quarries and separates them from the less uniformly colored slates of the Lehigh and Slatington districts which are not always able to retain their color unmodified by exposure. The only influence of exposure in the Peach Bottom slates which has been noticed, is a slight increase in the gloss or sheen in those pieces which have been longest exposed to the sun and atmosphere.

The bulk composition of any building stone may be very misleading, since it does not show in what state the chemical constituents are combined. This is especially true with slates. It, however, is of considerable advantage in showing the lack of injurious elements and the presence of advantageous components. The valuable constituents in the slates are the silicates of iron and alumina, while the injurious constituents are sulphur and the carbonates of lime and magnesia. Three analyses of the Peach Bottom slates are given below, one by the Pennsylvania Geological Survey made in 1877,[1] one by Booth, Garrett

[1] Second Report Laboratory of the Survey, by Andrew S. McCreath, Harrisburg, 1879, p. 370.

and Blair of Philadelphia in 1885, and one by George P. Merrill.[1] They are as follows:

Analyses of Slates.

	Pa. Geol. Sur.	B. G. & B.	Merrill.
SiO_2	55.880	58.370	44.15
TiO_2	1.270	tr.	tr.
Al_2O_3	21.849	21.985	30.84
FeO / Fe_2O_3	9.034	10.661	14.87
MnO	0.586	tr.	tr.
CaO	0.155	0.300	0.48
MgO	1.495	1.203	0.27
CoO	tr.	....	....
K_2O / Na_2O	4.100	1.933	4.36
H_2O	3.385	4.030	0.51
CO_2	....	0.390	4.49
C	1.974	0.930	....
S	....	0.107	wanting.
SO_3	0.22	....	"
FeS_2	0.051	....	"
	99.801	99.909	99.97

These analyses show the percentage of deleterious and advantageous minerals as follows:

	Geol. Surv.	B. G. & B.	Merrill.
Silicates of iron and alumina	86.763	91.016	89.86
Sulphur	0.039	0.107	wanting.
Carbonates of lime and magnesia	3.319	3.066	1.435

The source of the material for the first analysis was the "J. Humphrey & Co.'s quarry," now the Peach Bottom, and the second was also from the same opening. The material for the third analysis was taken from the opening of the Peerless quarry about one hundred feet west of the limits of the pit of the Peach Bottom. In describing the source of the materials Merrill gives the following description of the mode of weathering of the slates: "In the fresh cuts made during the work of stripping, to open new quarries, the sound rock is overlain by a variable thickness of ferruginous residual clay. Joint blocks and splinters of the slate scattered through this clay, in all stages of decomposition leave no doubt as to its origin. Blocks, deep velvety black on the interior, are surrounded by a crust of ocherous

[1] Rock, Rock Weathering and Soils, 1897, p. 229.

FIG. 1.—YORK AND PEACHBOTTOM QUARRY, CAMBRIA.

FIG. 2.—YORK AND PEACHBOTTOM QUARRY, CAMBRIA.

brown-red decomposition product, the decay penetrating irregularly like the processes of oxidation into a piece of metal. The first physical indication of decay is shown by a softening of the slate, so that it may be readily scratched by the thumb nail, and an assumption of a soapy or greasy feeling, the entire mass finally passing over to the deep red-brown unctuous clay, sufficiently rich in iron to serve as a low-grade ochre, for paints. The incidental chemical changes are surprisingly large, as shown by the analysis below, column I being an average of two analyses of one of the blocks, and II that of the residual clay. In III, IV, and V are given the calculated losses of constituents."

	I.	II.	III.	IV.	V.
Constituents.	Fresh Argillite.	Residual Clay	Percentage of loss for entire block.	Percentage of each constituent saved.	Percentage of each constituent lost.
SiO_2	44.15%	24.17%	25.34%	42.43%	57.57
Al_2O_3	30.84	39.90	0.00	100.00	0.00
FeO } Fe_2O_3 }	14.87	17.61	1.23	91.22	8.78
CaO	0.48	None.	0.48	0.00	100.00
MgO	0.27	0.25	0.08	71.84	28.16
K_2O	4.36	1.24	3.39	22.04	77.95
Na_2O	0.51	0.23	0.33	0.36	99.64
C	......	......	......	......	......
H_2O	4.49	16.62	0.00	187.37	None.
	99.97%	100.02%	40.85%	......	.....

Microscopical and physical examinations are even more important than chemical analyses in determining the stability of roofing slates which expose such a relatively large surface to the action of frost and solution. Merrill has based his discussion of the stability of slates upon the amount of crystallization as shown by the microscope and the presence or absence of free carbonates of lime and magnesia, sulphides of iron or of carbonaceous material. The most characteristic features of the microscopic structure of the Peach Bottom slates are as follows:

The most evident constituents are quartz, feldspar and chlorite. These are very small and indistinctly outlined against each other, as is usual in fine-grained slates. In the preparation of the slide the fibrous character of the stone which is evident upon larger pieces is especially prominent, and this is not wholly lost in even the thinnest parts of the slide. The material seems to be completely recrystallized

and no constituent is present in large areas which is at all untrustworthy. As the color seems to come from the chlorite and not from the finely comminuted particles of non-crystalline material, it should be permanent and unfading.

Professor Mansfield Merriman,[1] who has made a long series of experiments on the best methods of determining the durability of slates, regards physical and impact tests as most expressive of their permanency. An account of his experiments on the Peach Bottom slates is as follows: "During the present year the writer has made tests for strength, toughness, density, softness, porosity and corrodibility on twelve specimens of Peach Bottom slate, following the same methods as described in the former paper for the old Bangor and Albion slates. The specimens were 12 x 24 ins. in size, varying in thickness from 0.21 to 0.29 in. For the test of strength they were laid on supports 22 ins. apart and broken by a load slowly applied at the middle. The modulus of rupture for each case was then computed from the formula:

$$\text{Modulus} = \frac{3 \text{ x breaking load x length}}{2 \text{ x width x square of thickness}}.$$

"For instance, the specimen marked Q_1 was 12.04 ins. wide, 22 ins. between supports, 0.26 in. thick, and it broke under a load of 283½ lbs.; hence its modulus of rupture is 11,490 lbs. per square inch. The deflection, measured at the moment of rupture, was also noted as an index of toughness.

"The density of the specimens was determined by finding the specific gravity of each. The degree of softness was found by the weight abraded by 50 turns of a small grindstone under a constant pressure of 10 lbs. The porosity was determined by finding the percentage of water absorbed in 24 hours, after being dried for the same length of time at a temperature of 135° Fahr. The test for corrodibility was the percentage of loss in weight after immersion for 63 hours in a solution consisting of 98 parts by weight of water, 1 part of hydrochloric, and 1 part of sulphuric acid.

"The color of the slate was a dark bluish gray, or bluish black, and the texture of the surface was slightly scaly and soapy, being less

[1]Trans. Amer. Soc. Civil Eng., vol. xxvii, 1892, pp. 331-349; vol. xxxii, 1894, pp. 529-539.

smooth than the Northampton varieties. When ruptured by flexure, the specimens broke square across the grain without splitting or lamination. The tests for density, softness, porosity and corrodibility were made on pieces of the ruptured specimens.

"The table below gives the results of all the tests for each of the 12 specimens and also the mean values.

"An examination of these results tends to confirm the conclusions announced in the previous paper that in general the strongest specimens are the heaviest and softest, as also the least porous and corrodible, although exceptions occur in the case of Q_7 and P_2, and the Q specimens seem more corrodible than the P's, although greater in strength. The tests for strength and corrodibility are probably those of greatest importance in forming an opinion regarding the value of the slate under actual conditions of service. The test for softness, although a good one for a single lot of specimens, may not serve to fairly compare lots tested at different times on account of the varying conditions of the grindstone.

Mark of specimen.	Modulus of rupture in lbs. per sq. in.	Ultimate deflection in inches on supports 22 ins apart.	Specific Gravity.	Grains abraded by 50 turns of small grindstone.	Percent. of water absorbed in 24 hours.	Percent. of weight lost 63 hours in acid solution.
Q_1	11,590	0.32	2.886	69	0.265	0.247
Q_2	12,585	0.30	2.907	115	0.197	0.197
Q_3	8,400	0.30	2.900	110	0.304	0.291
Q_4	13,430	0.32	2.893	177	0.228	0.194
Q_5	8,320	0.28	2.900	75	0.264	0.237
Q_6	12,010	0.32	2.918	67	0.209	0.200
Q_7	14,210	....	2.890	111	0.278	0.341
Q_8	13,060	0.34	2.902	67	0.261	0.240
P_1	10,520	0.24	2.912	69	0.171	0.150
P_2	9,360	0.20	2.885	53	0.143	0.226
P_3	10,470	0.34	2.858	87	0.216	0.161
P_4	11,255	0.26	2.873	80	0.155	....
Means.	11,260	0.293	2.894	90	0.224	0.226

. . . . While the preceding methods of testing are readily carried on in the laboratory, they are not easily made under conditions of actual practice on account of the absence of precise weighing apparatus, and the lack of time and skill. It seems desirable that a test for slate should be devised which can be quickly applied by an architect or builder, and be used with confidence. An impact test, made by simply

dropping a ball, appeared one likely to yield good results, and accordingly a series of experiments has been carried on to determine what can be done in this direction. In connection with these, a series of severe acid tests has been made on the same specimens. . . . . The pieces of slate used in the impact test were 6 x $7\frac{3}{4}$ ins. Each piece was placed with the ends loosely clamped in grooved supports, so that it was approximately in the condition of a beam with fixed ends, the length between edges of supports being about $7\frac{1}{4}$ ins. and the width 6 ins. A wooden ball weighing 15.7 oz. was dropped upon the middle of the slate from a height of 9 ins., and the number of blows required to produce rupture was noted. The number of foot-pounds of work per pound of slate, expended in causing rupture, is a measure of the ultimate resilience of the material or of its capacity to resist shock, and thus is an index, both of its strength and toughness. Five specimens of each kind of slate were thus tested, and the table below gives the individual results and means. . . . As the result of the investi-

Specimen.	Thickness inches.	Weight ounces.	No. of blows.	Foot-pounds of work per pound of slate.
P_1	0.26	17.3	9	6.13
P_2	0.26	17.2	15	10.29
P_3	0.31	20.4	55	31.74
P_4	0.28	18.4	52	33.35
PP_4	0.29	20.4	68	39.33
Means	0.28	18.7	39.8	24.17
Q_1	0.26	17.2	11	7.54
Q_2	0.27	17.8	20	13.25
Q_3	0.29	19.3	17	10.39
Q_4	0.28	18.2	6	3.89
QQ_7	0.27	17.6	11	7.37
Means	0.27	18.0	13.0	8.49

Spec.	Percentages of loss of weight. After 120 hours.	After 240 hours.	After 360 hours.	Foot-pounds of work per pound of slate.	Specific gravity.
Q_3	0.45	0.90	1.27	....	....
Q_5	0.40	0.99	1.32	....	....
Mean	0.42	0.94	1.29	8.5	2.90
P_3	0.32	0.81	1.12	....	....
P_5	0.28	0.93	1.10	....	....
Mean	0.30	0.87	1.11	24.2	2.89

gations thus far made, it may be concluded that the tests for density and softness, although of importance for slates of the same locality, are not good indications of the strength and weathering qualities of those of different regions; that the tests for porosity, corrodibility and flexural strength give good indications of these properties; that the results found for strength and corrodibility when mentally combined give on the whole an excellent idea of the value of the slate; and that an impact test with a wooden ball shows both strength and toughness, while it at the same time indicates the capacity for resistance to corrosion."

IJAMSVILLE.

At the present time no slate is quarried at Ijamsville, although this locality has been known as a source of slate for nearly, if not quite, a hundred years. Parrish in his brief history of the slate trade in America states[1] that quarries "near Frederick" were opened about 1812. This may be a reference to the small openings at Linganore, but it seems more in harmony with local traditions to infer that the quarries about Ijamsville were in mind.

When Tyson prepared his report there were two slate quarries in operation. One was situated just west of the railroad station, beside the tracks, and the other was about a half mile south of the town. They were evidently quite small, for they had not reached the best material. Little work was done during the time of the Civil War, and the more prominent quarry, shown in Plate XXIV, Fig. 2, was permanently abandoned about 1870, when the "pit" commenced to undermine the roadbed of the Baltimore and Ohio Railroad. The smaller opening, lying south of the town, never attained any considerable importance, although efforts were made as late as 1892 to bring the product of this quarry into the market. The method of working followed was that of the Germans, who mine rather than quarry their slate. A shaft was sunk to a depth of about sixty feet, but the enterprise was not successful.

The slates from Ijamsville formerly brought nearly as good prices

[1] Amer. Jour. Mining, ii, 1866-7.

as those from Harford county,[1] but at the present time they are almost unsaleable. This is not due to the poor or unstable character of the stone so much as it is to the relatively poor workmanship displayed in recent years and the popular demand for a slate which will *ring* when tapped with a finger or pencil. Because of the hard and compact character of the better siliceous slates from Pennsylvania and the northern states, it has become customary to regard all dull or soft slates as untrustworthy. In many instances this view is correct, but in the case of the Ijamsville slates it is not warranted by the facts. The slates from this locality show microscopically that they are well crystallized, and that they do not owe their softness to a partial change from a shale to a slate, but to an admixture of the relatively stable and soft mineral talc, which is usually wanting in the better known slates. If the stone were unstable the blue-black color would change upon exposure. This it does not do, since roofs on which the slates have been exposed to the atmosphere for fully fifty years do not indicate any change in color as a result of this exposure. In spite of their permanency in color and their strength the slates have yet to prove themselves a basis for a profitable industry.

[1] The price per ton for the Harford county slates, as given by Tyson, ranged in 1860 from $12 to $22, which would be approximately from $4 to $6.50 per square. The prices for the Ijamsville slates were: "First quality, $5 for 560 lbs., which cover 100 square feet; second quality, $4 for 620 lbs., which cover 100 feet." The quality of the slates furnished was probably about equal to that of the Lehigh slates of to-day.

THE BUILDING-STONE TRADE.

Collection of Statistics.

Any discussion of the statistics concerning the building-stone industry in Maryland or any other state must be limited to conditions obtaining during the last ten or fifteen years, and even within these limits the figures obtained are far from satisfactory. There is probably no line of statistical work which offers a greater number of discouraging features in proportion to the problems involved than that connected with the quarrying industries. These difficulties arise from several causes. Prior to the inauguration of statistical work by the U. S. Geological Survey there seems to have been no attempt at the uniform collection of annual figures regarding the output of building stone within the limits of the United States. The only exceptions to this statement are found in the tables presented in the Eighth, Ninth and Tenth Census Reports made in the years 1860, '70 and '80 respectively. Earlier reports of this nature either made no enumeration of the industry based on actually gathered statistics, or their classification is such as to render comparison with later data of little value.

The work of the U. S. Geological Survey in the collection of statistics has been noteworthy, and a marked increase in the amount of information concerning the building-stone industry is evident from year to year. The first reports of this organization were based upon the Tenth Census, and it was not until the year 1884 that any considerable amount of material was collected concerning the granite industry of the different states. At the beginning of their work the agents of the Federal Survey met with many discouragements which have been encountered anew in the prosecution of the present work. The greatest source of delay and lack of details arises from the attitude of the quarrymen themselves, who disregard written communications and even refuse to impart information to members of the Survey. The grounds for this attitude among the quarrymen are

due to various reasons. Sometimes no record has been kept of the amount of the product which has been shipped, and in other instances the record preserved is in such shape that little of a statistical nature can be gathered. Among those operators who preserve a careful record of their output, expenses and wage list, there are many who refuse to give information because they have been so annoyed by the importunities of unauthorized gatherers of statistics, who make unwarranted requests on the time and information of the quarrymen, that they fail to make a discrimination between demands which are legitimate and those beyond all reasonable bounds. Many of the trade journals and similar organs have gathered statistics from year to year and published them in such a way that trouble has arisen between the employers and the employees, until the operators are almost afraid to give even the most commonplace information. Other statistics gathered from various sources have been utilized by the tax collectors and other petty officials as a basis for exorbitant demands, until the quarrymen feel that information may be used against them in almost any conceivable way. Before satisfactory statistics can be gathered concerning the various phases of the quarrying and marketing of stone, it will be necessary to overcome all of these misunderstandings and prejudicial notions held by the quarrymen.

Annual Production in Maryland.

Considering all of the available sources of information, of which the most trustworthy are the reports of the U. S. Geological Survey, it has been possible to construct the following table which approximately represents the annual output of the quarries within the state during the years 1860 to 1897 inclusive.

A study of these columns gives only an inadequate conception concerning the fluctuations of trade which have occurred during the last half century. So much depends upon the conditions under which the statistics were gathered and the minimum limit of output recorded that it is of little use to make a detailed study of the individual industries. There are, however, a few facts concerning the statistics obtained in different years as recorded by the various statistical bureaus which are of interest.

VALUE OF ANNUAL PRODUCTION IN MARYLAND.

	Granite.	Sandstone.	Slate.	Marble.	Limestone.	Total.
1860	46,900	......	26,000	30,000	224,630	.....
1870	85,229	......	80,853	275,000	234,199	......
1880	224,000	......	56,700	65,929	......	......
1881	......	......	......	.....	......	......
1882	......	......	......	......	......	......
1883	......	......	......	......	......	......
1884	......	......	45,000	......	......	......
1885	......	......	65,250	......	......	......
1886	......	......	54,000	.....	......	......
1887	. ...	......	90,000	160,000	429,000	......
1888	263,952	[15,000]	85,500	175,000	[175,000]	......
1889	447,489	10,605	110,008	119,675	164,860	872,778
1890	447,489	10,605	110,008	139,816	164,860	872,778
1891	450,000	10,000	125,425	100,000	150,000	835,425
1892	450,000	5,000	116,500	105,000	200,000	867,500
1893	260,855	360	37,884	130,000	......	......
1894	308,966	3,450	153,068	175,000	350,000	990,484
1895	276,020	16,836	60,357	145,000	200,000	698,214
1896[1]	251,108	10,713	72,142	110,000	264,278	708,241
1897	188,335	[10,000]	53,939	106,000	249,809	608,083

Granite.—Since the war the granite industry has shown a slight but steady increase in the amount of its output, which is not fully brought out by the increasing values of the annual product. The reason for such an increase in volume seems to lie in the growing demand for granite in all sorts of structures and in the slight cheapening in the cost of extraction and dressing. These conditions are accentuated by the gradual change in public taste respecting the use of trimming stones, which demands gray sandstones and granites in place of the brownstones. The latter now hold a far less important position in the market than in the years immediately succeeding the Civil War. During these years there has also developed a considerable trade in paving stones and road metals which has allowed the utilization of the angular blocks and waste of the quarries, thereby decreasing largely the expense of operation. The trade seems to be moderately uniform and somewhat similar to the oscillations in the general demand, as, for example, in June, 1893, there was a marked falling off in the output, the only shipments being in fulfillment of

[1] See note p. 241.

orders already presented. The trade recovered temporarily in 1894, but has since then been in even a more discouraging condition than at any time during the last decade.

Sandstone.—The sandstone industry is the most variable among all of the quarrying industries carried on in the state. During the years 1875 to 1884, no work was carried on at the Seneca. This stagnation in business was due to the strong reaction against brownstone and other sandstones which swept over the country about 15 or 20 years ago. During the years 1888 to 1891 there was considerable activity, but the sandstone industry felt the general depression of '93 so strongly that the reports indicate almost no output. Later, as the companies became active, the product increased somewhat and is at the present time about normal. In fact, there seems to be a slightly growing demand for high grade brownstone which may in time supersede the lighter colored stone as trimming.

Marble.—The marble industry has been almost constant throughout the last ten years, showing only slight relative changes in the value of the product, which averages about $140,000 annually. This is the only industry which did not seem to feel the depression of '93, a fact which is due no doubt to the uniform product and uniform demand for the Cockeysville marble, which furnishes most of the material within the state. Some of the fluctuations between the different years may be accounted for by the oscillations in the serpentine output, since this is included among the marbles.

Slate.—The nearest complete details concerning the actual output of the quarries are available respecting the slates. This no doubt arises from the peculiar nature of the manufacture and the high skill and intelligence required in the preparation of slate stock for the market. Unlike that of the other building stones, the manufacture of slate requires a special skill which is usually acquired by practice from childhood. This fact influences greatly the product of the various quarries, for it is regarded by the operator as more disastrous to discontinue operations than to be left with a surplus of stock. The labor, because of its peculiar skill, cannot be replaced at will, and the quarrymen thrown out of their customary employment are unfitted to

engage in other lines of industry. This method of procedure requires an increased capital, which in turn has rendered the profits much less during periods of depression, since there is no compensating reduction in the wages of the quarrymen.

Prices, Wages, etc.

The facts which have been gathered from personal conversation with quarrymen and contractors over the entire state are so at variance with one another, especially concerning the price, that it has been impossible to obtain any mean values which satisfactorily represent the average price per foot for the different products throughout the state. With the exception of the highest grade work, and the product of one or two of the larger operators, there is no systematic regularity in the price charged for products of the same kind and quality, the prices even varying 20 to 40 per cent on opposite sides of a hill connected by a deeply cut valley which eliminates variations due to differences in the price of hauling. The same fact is true concerning the gneisses quarried about the city of Baltimore, where the figures given for different quarries show a variation in the price of random rubble, for example, of fully 150 to 200 per cent. The prices for the different products are given in subjoined tables, from which it may be seen that the same material when sold by different standards is really sold at quite different prices, as, for example, when rubble-gneiss is sold at the rate of $2 a cubic yard ($1.38 per perch), $1 per long ton ($.74 per perch) and $1 per perch. The figures gathered likewise do not show a uniform difference in price between the labor and the product in the counties and those in the vicinity of Baltimore, although the price is usually lower in the country districts for both, except among the skilled laborers belonging to unions which regulate the wages. Even here at times there seems to be an unfairness toward the city artisan, since he is compelled to pay somewhat more for living expenses than his competitor outside of urban influences.

The actual information in these tables is limited by the confidential nature of the facts given and the unwillingness in certain instances to impart any sort of statistics because of previous breaches in con-

fidence by unofficial agencies. The wages are generally fixed by the unions to which most of the skilled workmen belong. Considering the capital invested, the wear of machinery and the value of the stone in the ledge, the margin between the cost of extraction and the price of the finished product is not excessive.

GRANITE AND GNEISS.

	Undressed Stone.		Cost of Dressing.	Wages.		Prices at Quarry.			
	Per foot.	Royalty per perch.		S.	L.	Per perch.	Per yd.	Per cu. ft.	Per ton M
Rubble	......	......	....	$3.50	$1.00	...	$1.00	...	....
	......	......	....	1.80	...	...	...	...	....
Flagging	......	......	....	...	...	...	...	.30	....
	......	......	....	...	...	...	...	.35	....
Curbing	......	......	....	...	...	...	...	.30	....
	......	......	....	...	...	...	...	.35	....
Paving	......	......	....	...	...	...	...	.25	....
	......	......	....	...	...	...	...	.30	....
Belgian blocks	......	$10 per M.	....	...	...	...	...	...	....
Dimension	.60–1.25	......	....	...	...	...	...	...	....
Monumental	.70–1.25	......	....	...	...	...	...	...	....
Rubble	......	.05	....	3.00	1.00	.80	2.00	...	....
	......	......	....	...	1.25	1.50	...	...	....
Flagging	.21	......	....	...	...	...	...	.28	....
	......	......	....	...	...	...	...	.56	....
Curbing	......	......	6–10	...	...	...	...	.35	....
	......	......	....	...	...	...	...	.60	....
Coping	......	......	8	...	...	...	...	.45	....
	......	......	....	...	...	...	...	2.00	....
Dimension	......	......	....	3.50	1.50	...	...	...	....
Pointed	......	......	....	3.00	1.25	...	...	.65	....
	......	......	....	...	...	...	...	.75	....
Ax hammered	......	......	12–15	...	...	...	...	.65	....
	......	......	....	...	...	...	...	1.50	....
Bush hammered	......	......	32–33	...	...	...	...	1.02	....
Belgian blocks	......	$10 per M.	....	...	...	...	1.80	20	$45
	......	......	....	...	...	...	...	...	59

TRIASSIC SANDSTONE.

	Cost of Undressed Stone.		Wages.	
	Cu. ft.	Royalty per perch.	S.	L.
Rubble	.60—$1.50	.25	$3.50	$1.25
	....	....	3.00	1.25

PALEOZOIC SANDSTONE.

	Cost of Undressed Stone.	Wages.	
			L.
Rubble	$1.00—$3.00 per cu. yd.	$1.35—$1.45	$1.25
Flagging	1.45 per sq. yd.	......	....
Macadam	.70 per perch.	......	....

The wages in Allegany and Garrett counties are lower than in Montgomery and Frederick since the industry in the latter localities is more firmly established and the product of a higher grade. The variations in price for the same material according to the units of measurement are noticeable in the sandstone reports, but they are not so extreme as in the gneiss and granites.

All of the product of the Peach Bottom area is used for roofing slates, since the grain of the rock is rather against its being used for milling purposes. Thus the above prices represent the figures for almost the entire output of the region. The slate trade maintains the price of stock more uniformly than almost any other of the stone quarrying industries, for the prices obtained to-day are nearly the same as those obtained seventy-five or eighty years ago. The method of reckoning has changed from weight to area of roof, and the "lap" of the upper courses of the latter has during the years increased from two to three inches in the higher grade materials. The manner of estimating the number of pieces per square is based on the practice in laying slates. The slates are laid so that the first course is overlain by the second course and by two or three inches of the third. The overlapping of the first third courses is known as the "lap," and it is not unusual for the roofer to buy his stock with a "three-inch lap" and lay it with only a "two-inch lap," thereby saving for himself a small margin which does not appear to the consumer. Moreover, the workmanship and uniformity in the product has greatly improved so that, although the apparent price remains the same, there has been a steady improvement in the material furnished to the consumer.

The following list of prices does not represent any except the standard thickness of three-sixteenths inches. That is, the stock runs about four pieces to the inch "in the rick." When the speci-

SLATES.

		Md. & Pa. Slates.		Pa. Slates.				Maine Slates.		Vermont Slates.		
Size.	No. Pieces 3 lap.	Peach Bottom 98.	Peach Bottom 95.	Northampton Co.	Washington.	Franklin Tunnel.	Lehigh, No. 1.	Maine, No. 1.	Maine, No. 2.	Unfading Green.	Bright-red.	Buckingham Co., Va.
9x7	686							3.50	2.50			
10x5	823	3.05	3.25									
10x6	686	3.50	3.50								7.00	
10x7	596	3.50	3.50								7.00	
10x8	514	3.50	3.50					4.00	3.00		7.00	
11x5	720	3.35	3.50									
11x6	600	3.65	3.75									
11x7	514	3.65	3.75									
11x8	450	3.65	3.75					4.50	3.50			
12x6	534	4.50	4.75	3.20	3.10	3.55		4.80	3.80	4.00	9.00	
12x7	458	4.60	4.75	3.25	3.20	3.55		5.00	4.00	4.00	9.50	
12x8	400	4.60	4.75	3.25	3.25	3.55		5.50	4.50	4.00	9.50	
12x9	356	4.60	4.75					5.60	4.60	4.00	9.50	
12x10	320	4.60	4.75					5.80	4.80	4.00		
14x7	374	4.85	5.25	3.50	3.40	3.95		6.40	5.40	4.50	11.	3.60
14x8	328	4.85	5.25	3.75	3.40	3.95		6.60	5.50	4.50	11.	3.60
14x9	291	4.85	5.25	3.75				6.50	5.50	4.25	11.	3.60
14x10	262	5.00	5.25					6.60	5.60	4.25	11.	3.60
14x12	219							6.50	5.50			
14x14	187							7.00	6.00			
16x8	277	5.10	5.60	4.40	3.75	4.25	3.00	7.20	6.20	4.50	11.	4.00
16x9	247	5.10	5.60	4.40	3.75	4.25		7.00	6.00	4.50	11.	4.00
16x10	222	5.00	5.50	4.40	3.75	4.25		7.10	6.10	4.50	11.	4.00
16x11	202	5.00	5.50					6.90	5.90	4.25		
16x12	185							6.80	5.80	4.00		
16x16	139							7.00	6.00			
18x9	214	5.10	5.60	4.30	3.75	4.25	3.00	7.10	6.10	4.50	11.	4.00
18x10	192	5.10	5.60	4.30	3.75	4.25		7.20	6.20	4.50	11.	4.00
18x11	175	5.00	5.50					7.00	6.00	4.25		
18x12	160	5.00	5.50					6.80	5.80	4.00		3.60
18x14	137							6.50	5.50			
20x10	170	5.10	5.60	4.20	3.75	4.25	3.00	6.80	5.80	4.50	11.	4.00
20x11	154	5.00	5.50	4.20				6.80	5.80	4.25		
20x12	142	5.00	5.50	4.20	3.50	4.25		6.90	5.90	4.25		3.60
20x13	130	5.00	5.50									
20x14	121									4.00		
22x11	138	5.00	5.50	4.00	3.35	3.80	3.00	6.50	5.50	4.25		3.60
22x12	127		5.50	4.00	3.35	3.80		6.60	5.60	4.00		3.60
22x13	116		5.50									
22x14	108		5.50							4.00		
24x12	115	5.00	5.50	3.80	3.25	3.50	3.00	6.60	5.60	4.00		3.60
24x13	105	4.85	5.35	3.80								
24x14	98	4.85	5.35	3.80		3.45		6.10	5.10	4.00		3.60
24x15	91	4.75	5.15									
24x16	85	4.75	5.15									

fications call for one-quarter inch stock, sawed edges, polished surfaces or boring and countersinking, the price increases somewhat per square according to the character of the work required. The Peach Bottom slates do not need to be drilled and countersunk as much as some of the more brittle slates from the northern states, since when punched, the hammer goes through, making a clean hole without any injurious flaking or spalling on the underside.

The figures in the foregoing table show that there has been a decrease in the prices obtained for the Maryland slates since 1895, and that the material from the New England quarries demand higher prices than that for Maryland, while the prices of the Virginia and Lehigh slates are lower.

NOTE.—The figures indicating the annual product for 1896 are those published by the U. S. Geological Survey. Although they are different from the results obtained in the exhaustive investigations carried on by the State Geological Survey, they are more valuable for a comparative study, since the conditions governing their collection and tabulation are more in accord with those existing in previous years.

ır Fe '06

With the Compliments of Geo P Merrill

MARYLAND GEOLOGICAL SURVEY

WM. BULLOCK CLARK, STATE GEOLOGIST.

THE BUILDING AND DECORATIVE STONES OF MARYLAND

Containing an

Account of their Properties and Distribution.

BY

GEORGE P. MERRILL AND EDWARD B. MATHEWS.

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